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Kim et al.

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(54) **SEMICONDUCTOR DEVICES AND METHODS OF MANUFACTURING THE SAME**

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H01L 21/762 (2006.01)
H01L 27/02 (2006.01)

(52) **U.S. Cl.**
CPC **H01L 27/10855** (2013.01); **H01L 21/76224** (2013.01); **H01L 27/0207** (2013.01); **H01L 27/10814** (2013.01); **H01L 27/10876** (2013.01); **H01L 27/10885** (2013.01); **H01L 27/10888** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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Primary Examiner — Bilkis Jahan

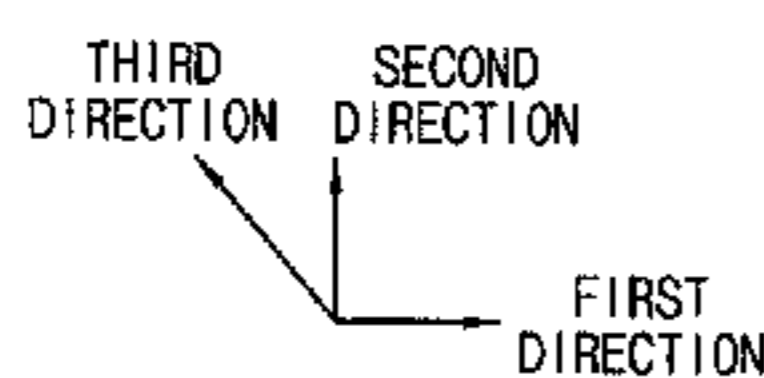
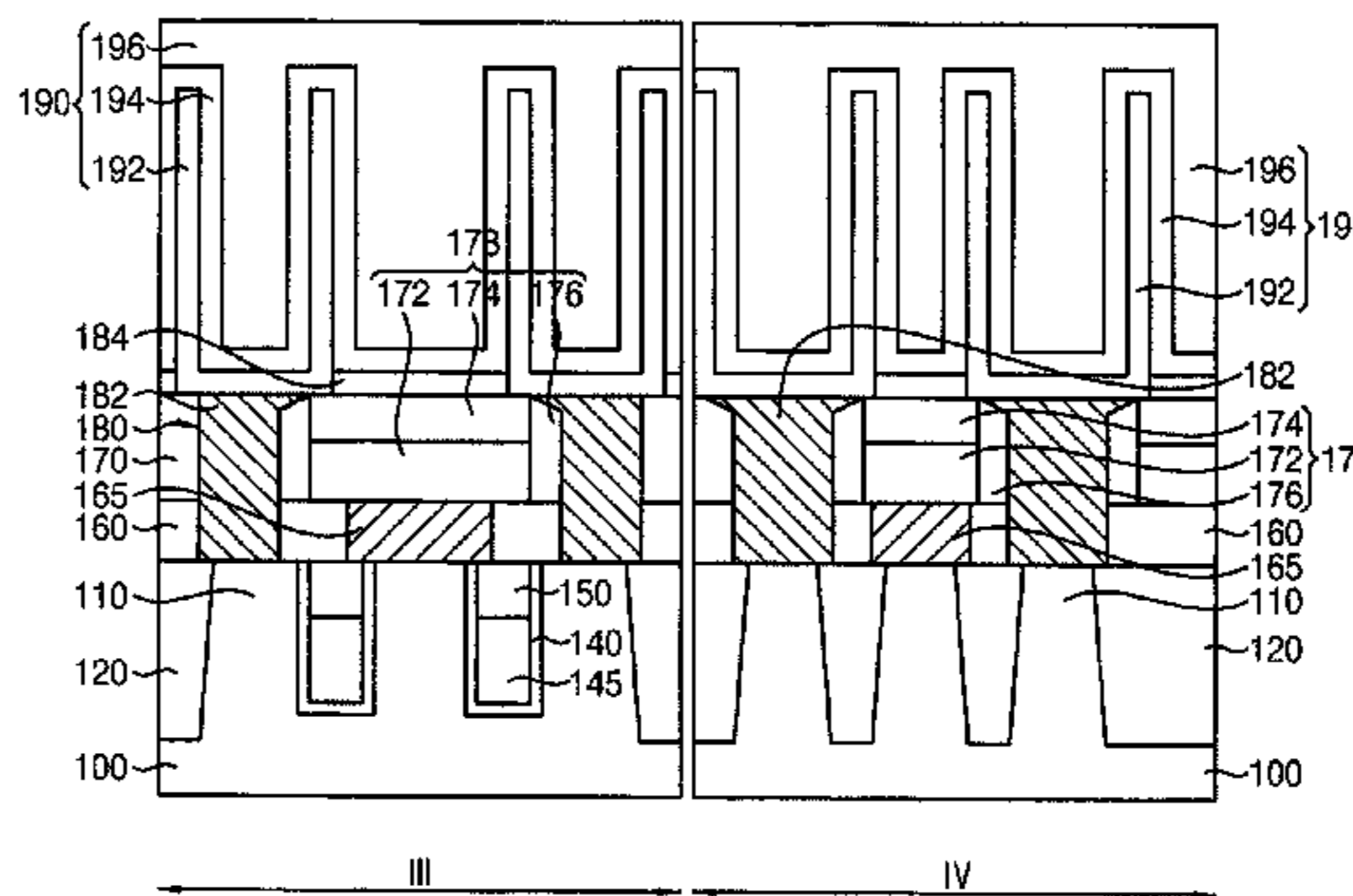
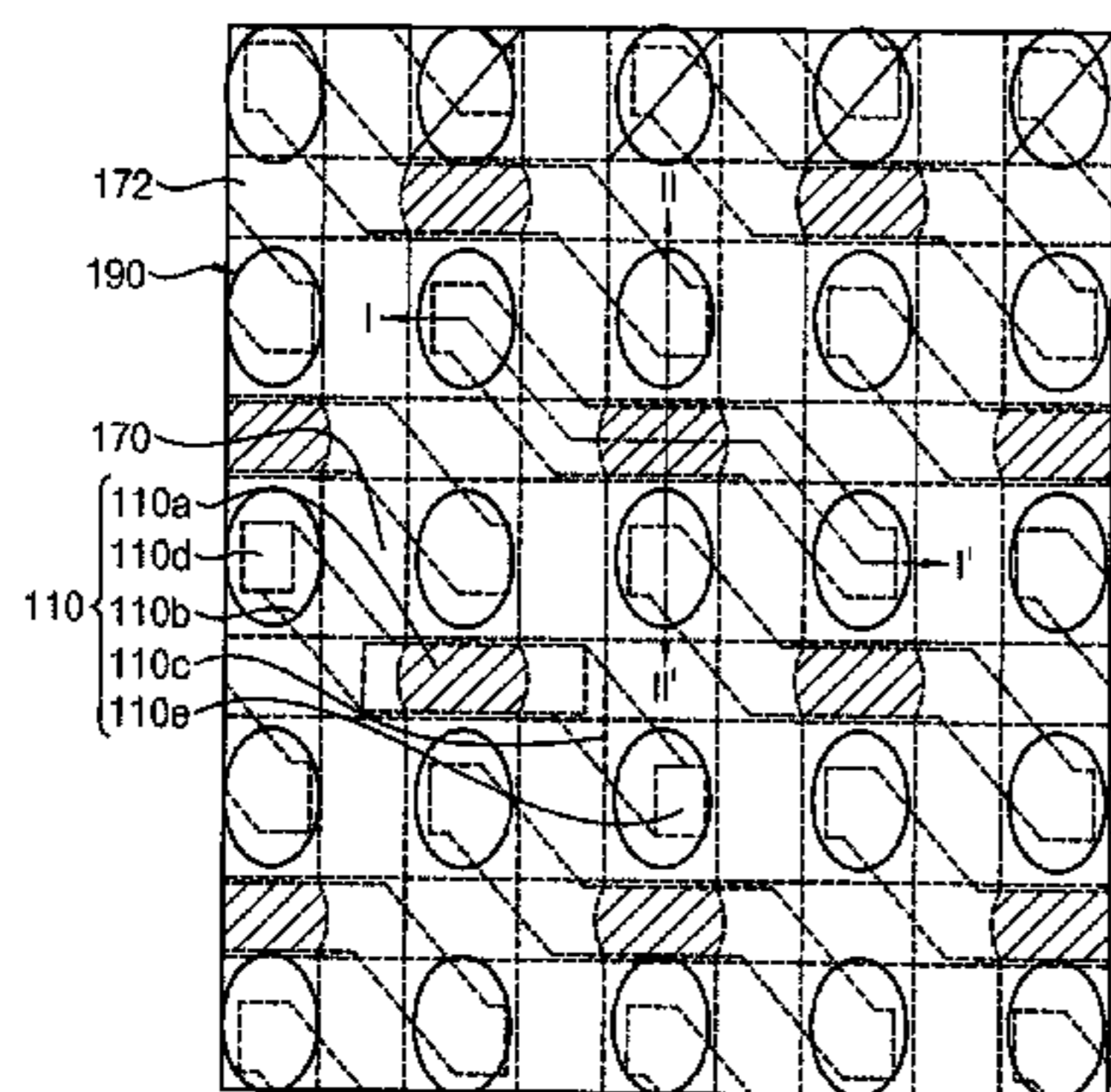
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(57) **ABSTRACT**

A semiconductor device includes a substrate with an active pattern, the active pattern having a first extension portion extending in a first direction substantially parallel to a top surface of the substrate, a second extension portion extending from a first end of the first extension portion in a third direction oriented obliquely to the first direction, a third extension portion extending from a second end of the first extension portion in a direction opposed to the third direction, a first projection portion protruding from the second extension portion in a direction opposed to the first direction, the first projection portion being spaced apart from the first extension portion, and a second projection portion protruding from the third extension portion in the first direction, the second projection portion being spaced apart from the first extension portion.

20 Claims, 23 Drawing Sheets



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FIG. 1

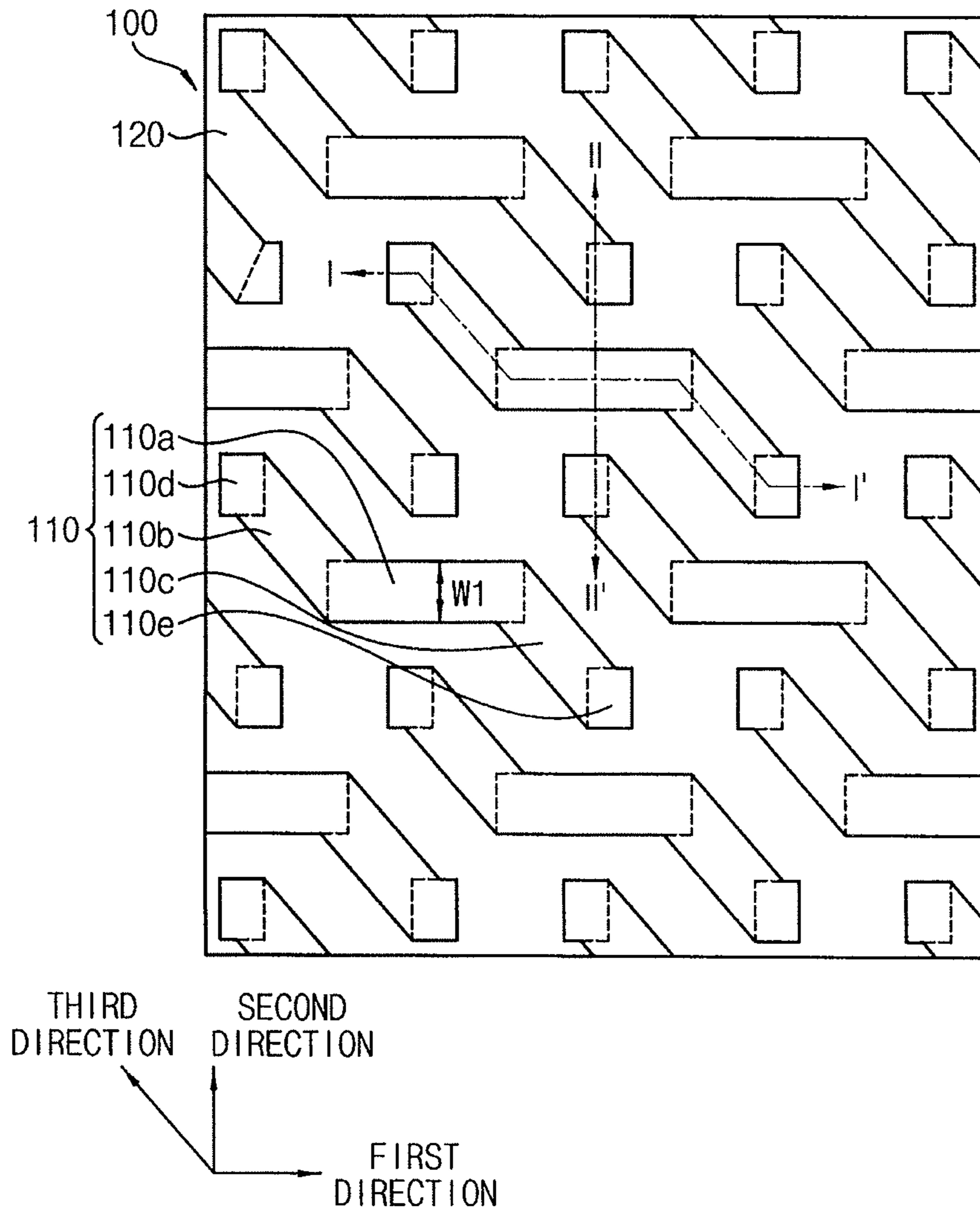


FIG. 2

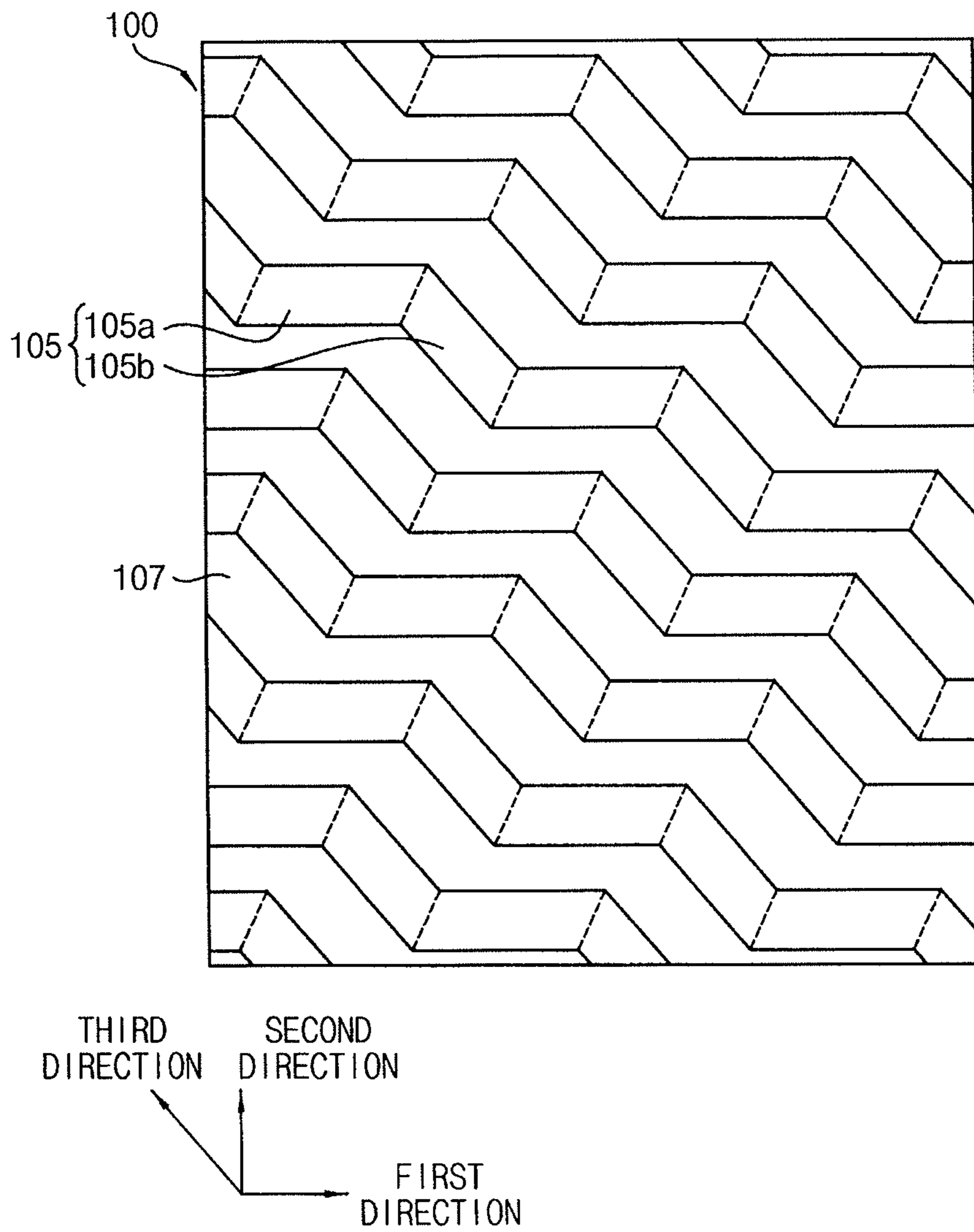


FIG. 3A

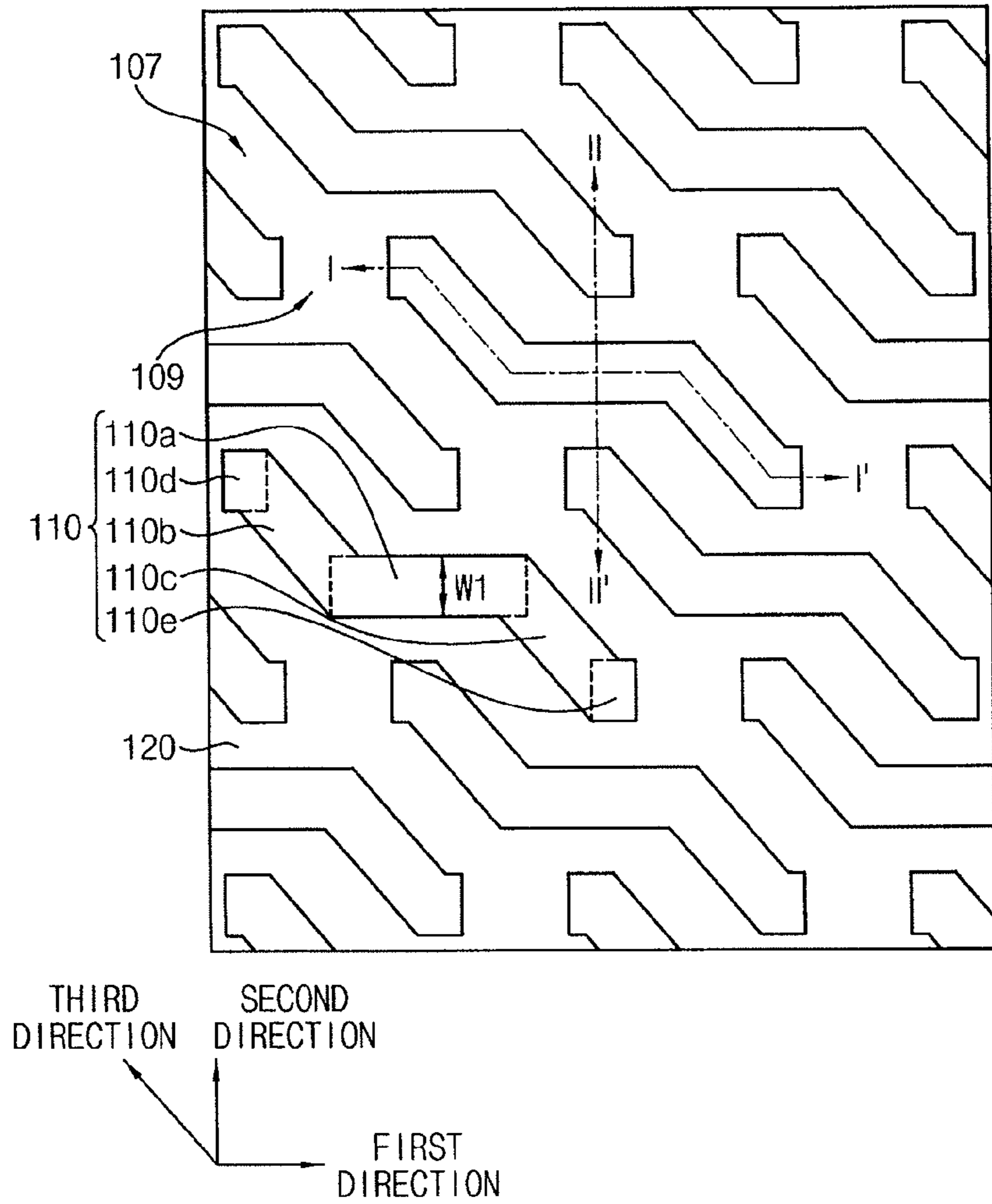


FIG. 3B

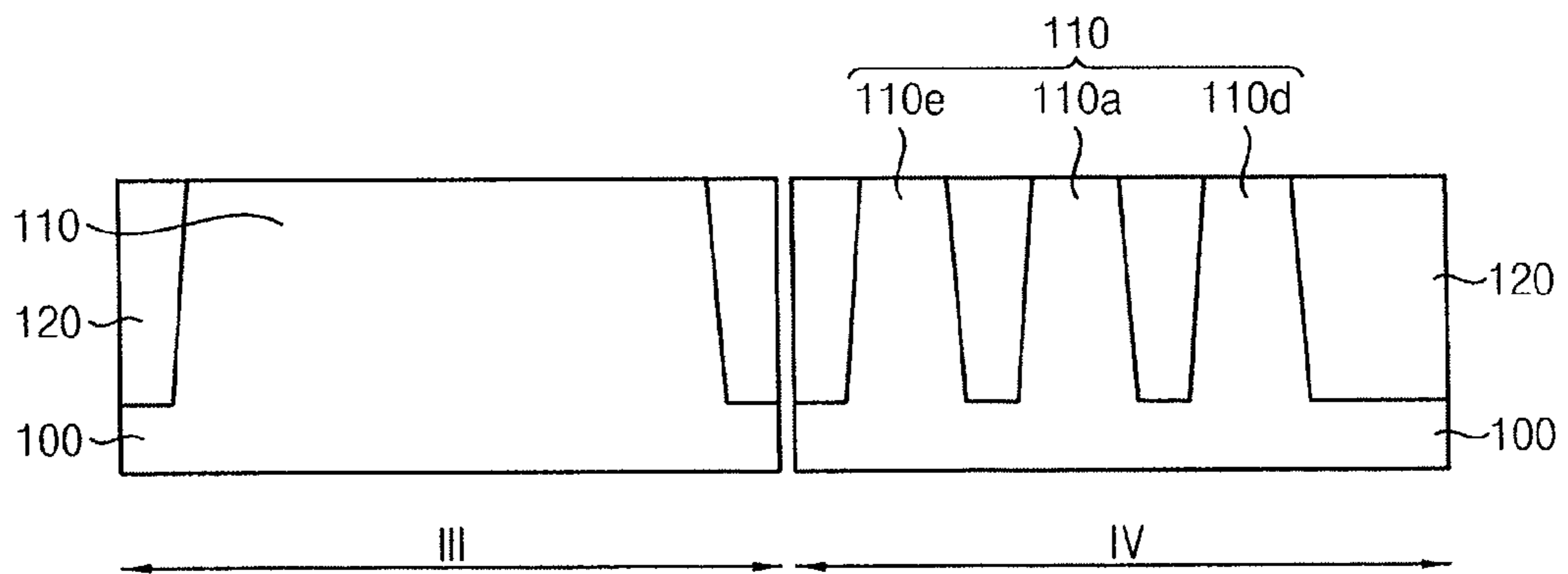


FIG. 4A

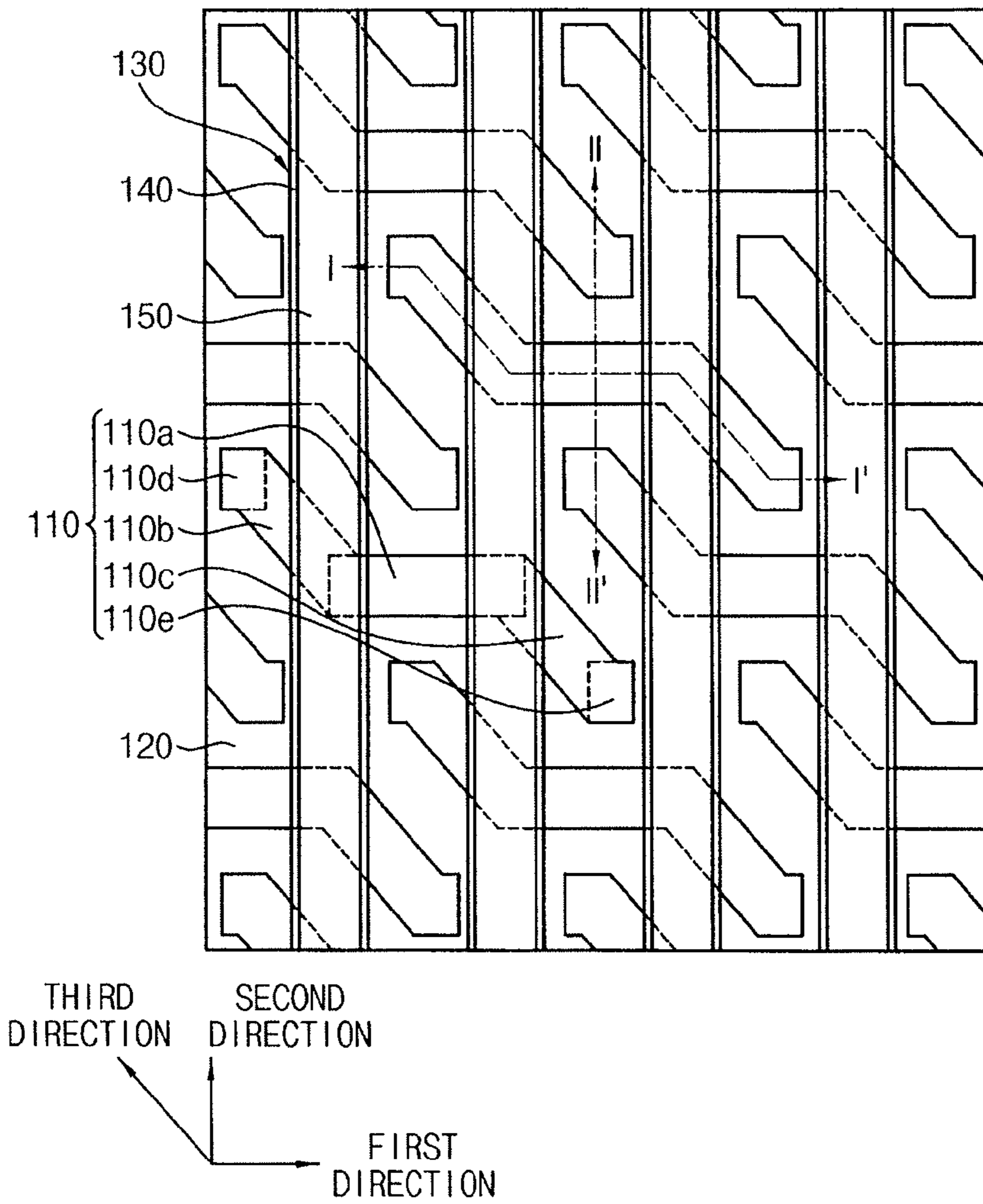


FIG. 4B

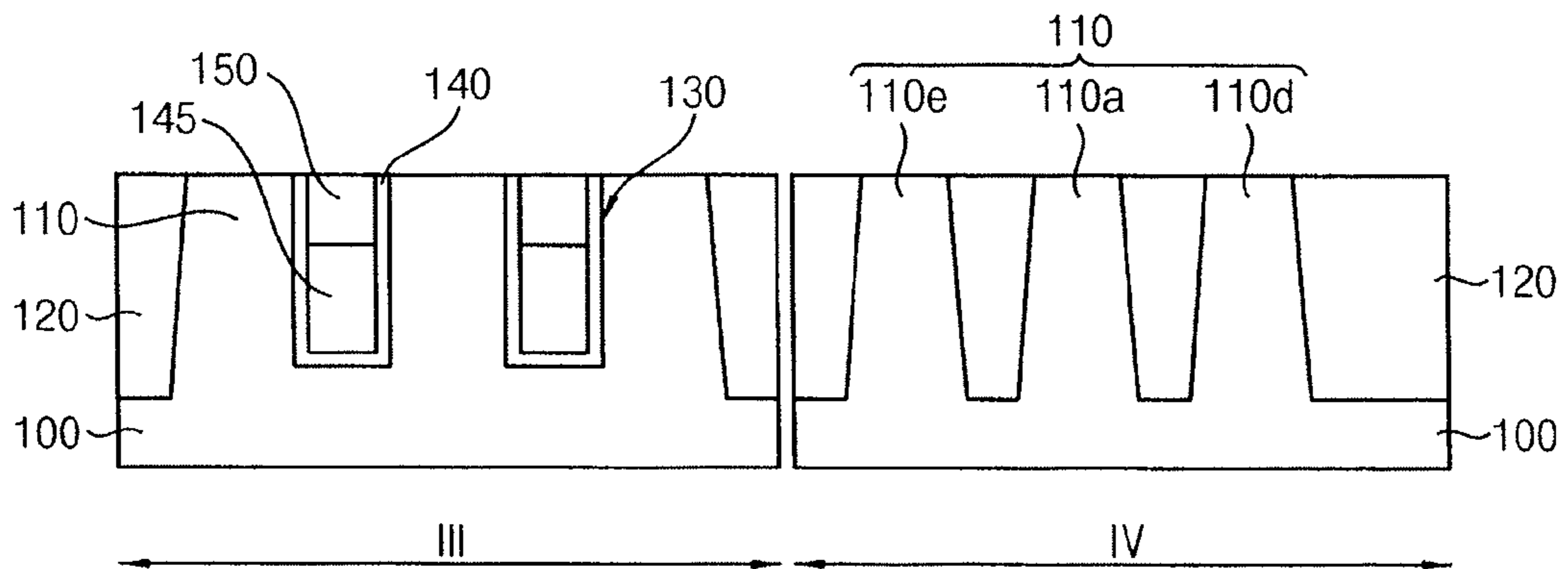


FIG. 5A

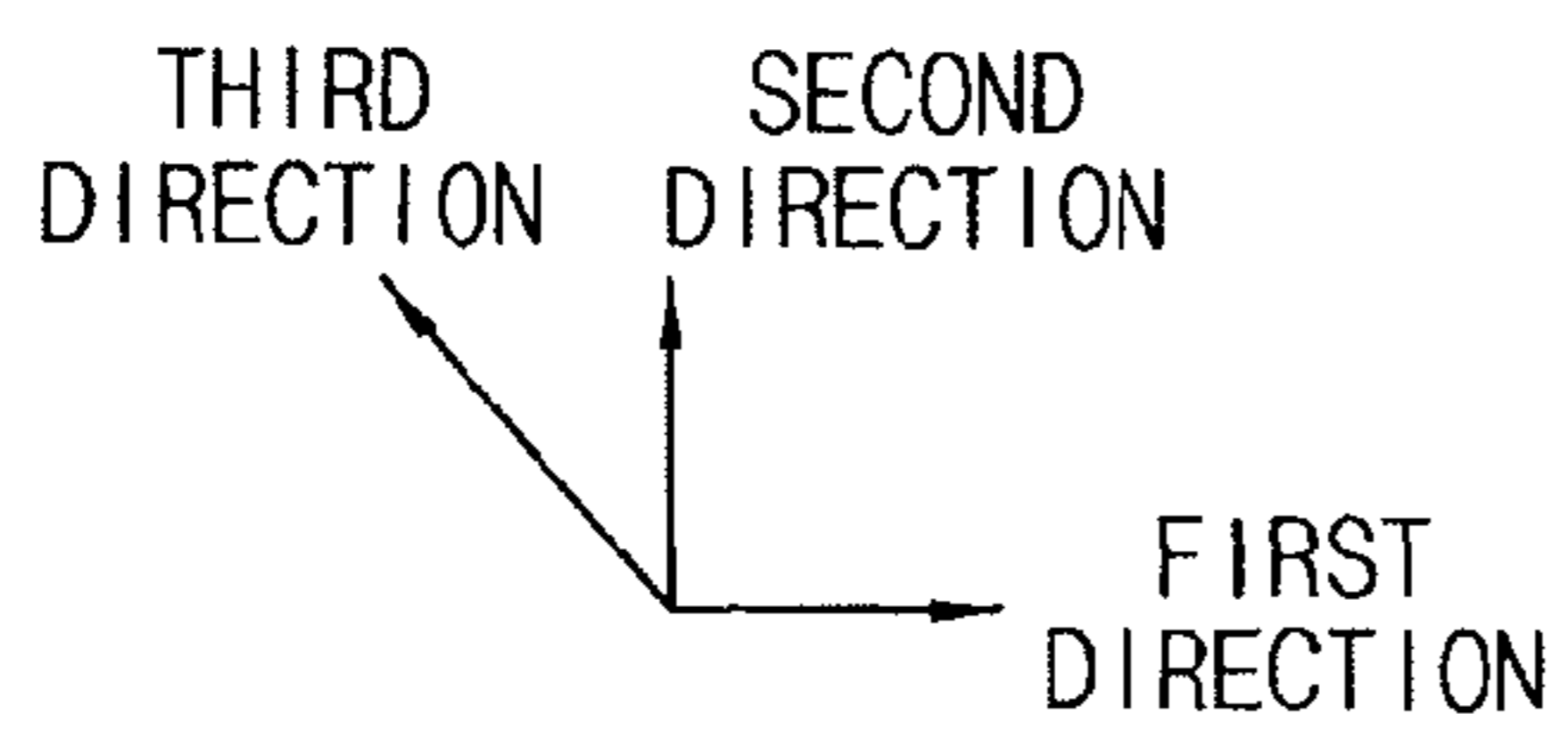
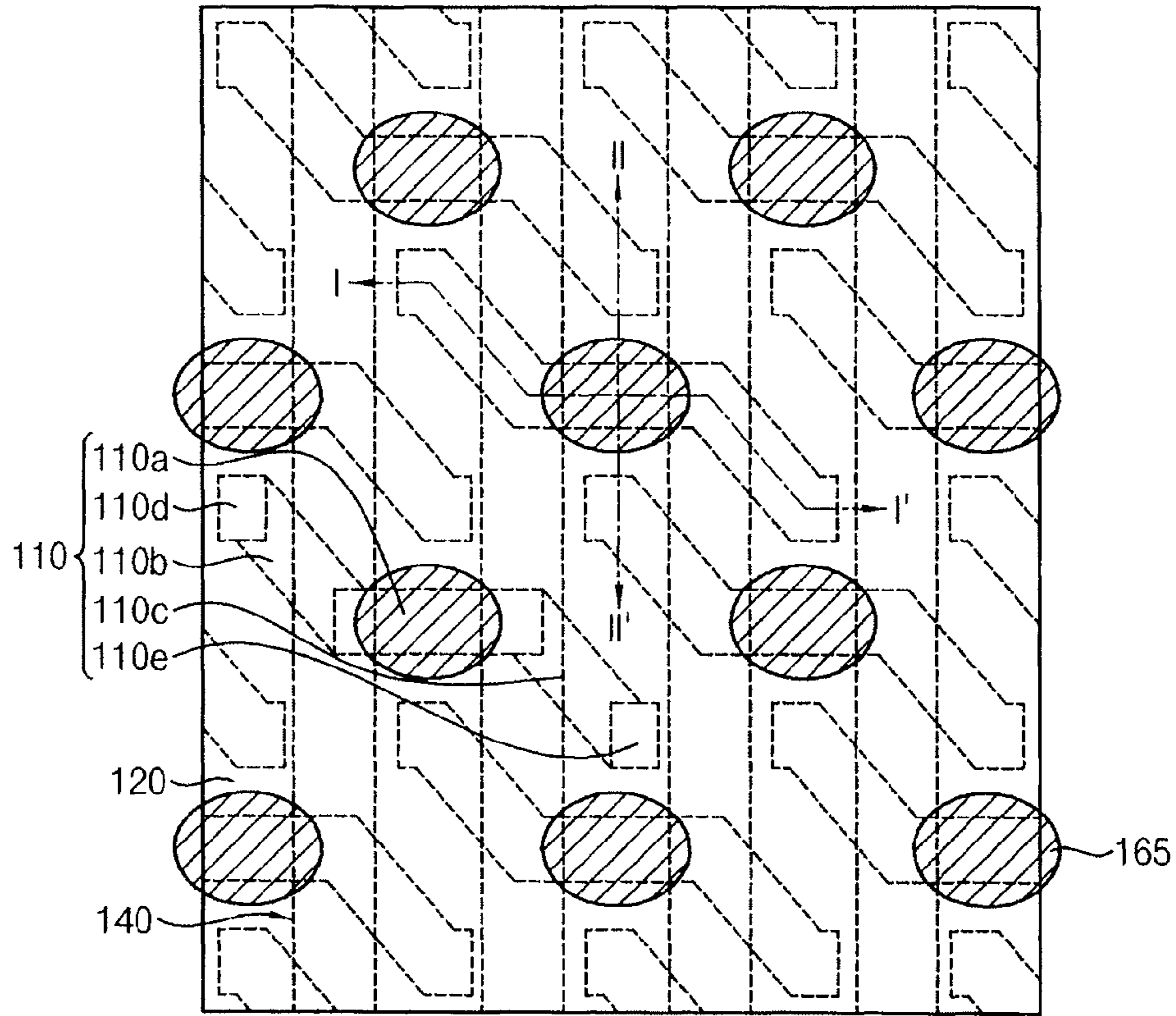


FIG. 5B

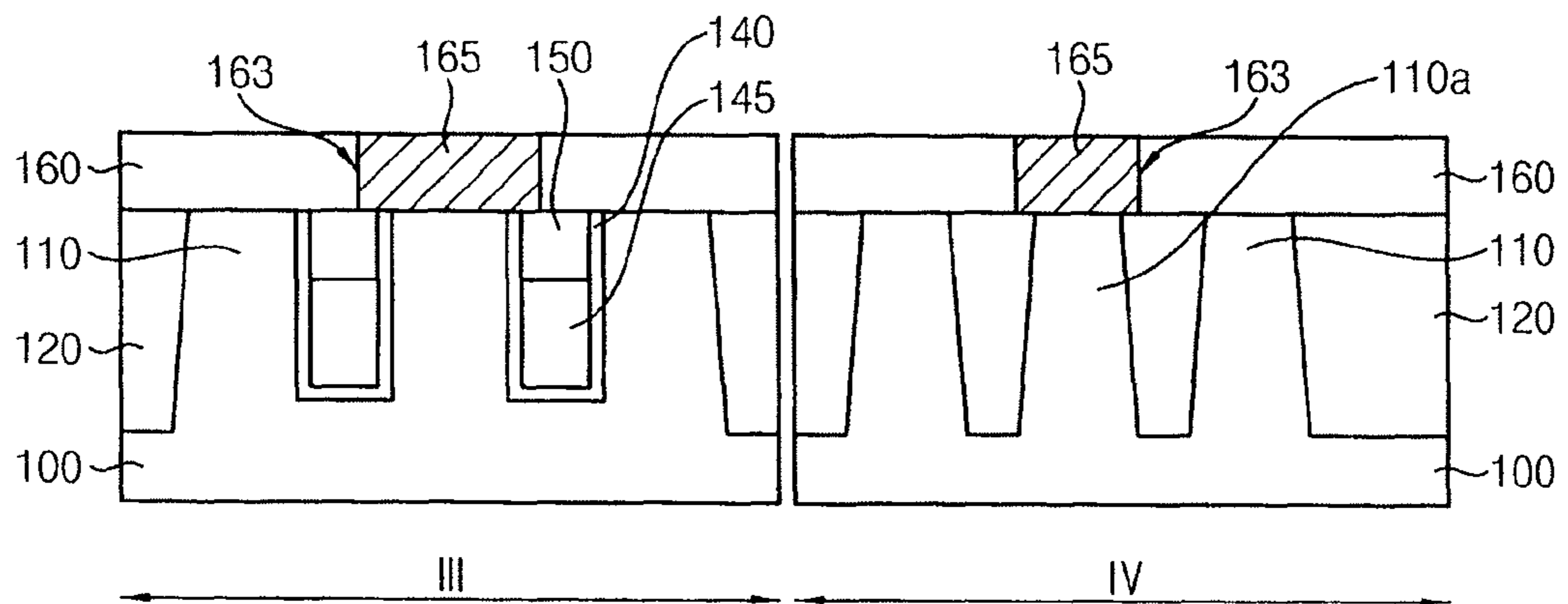


FIG. 6A

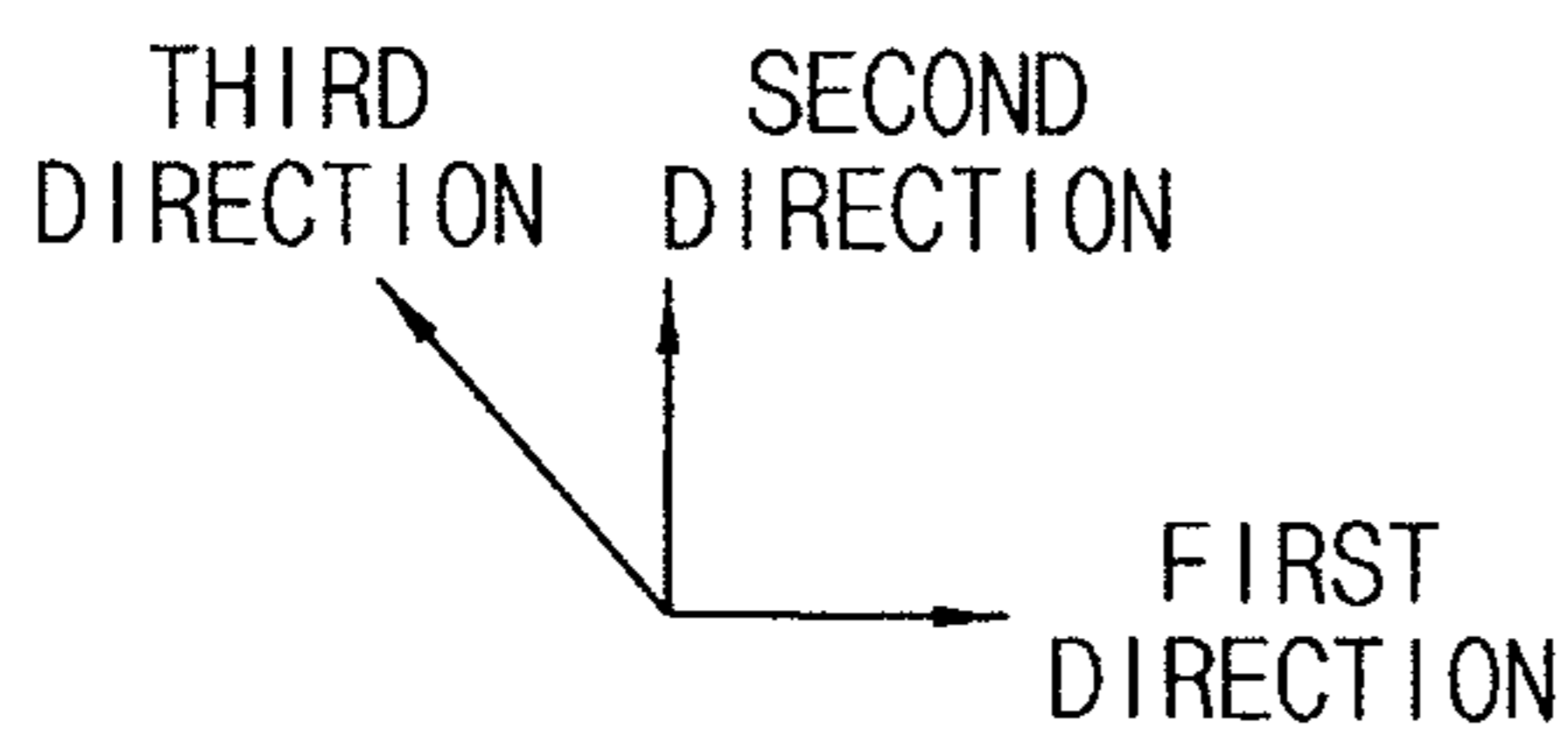
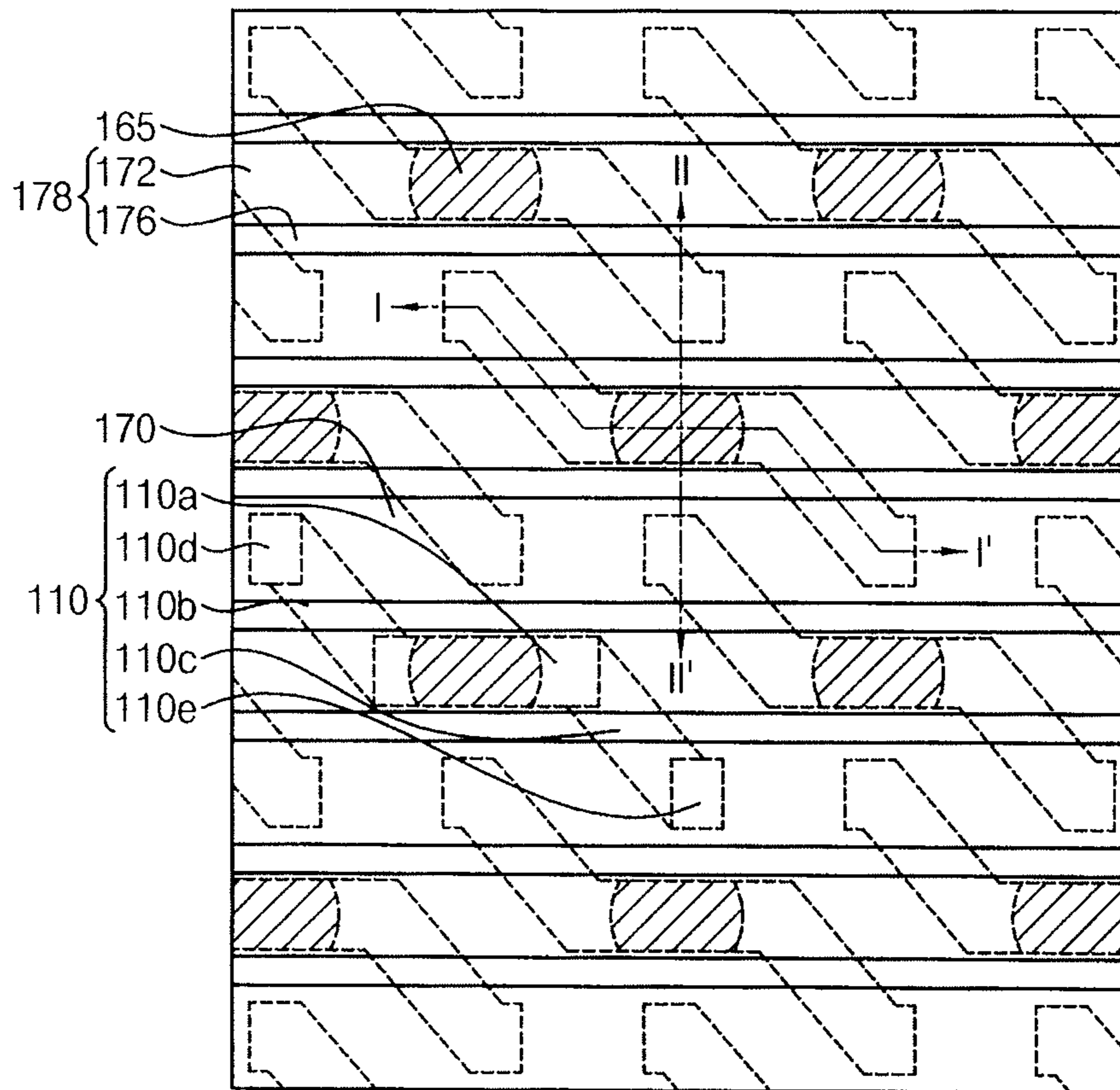


FIG. 6B

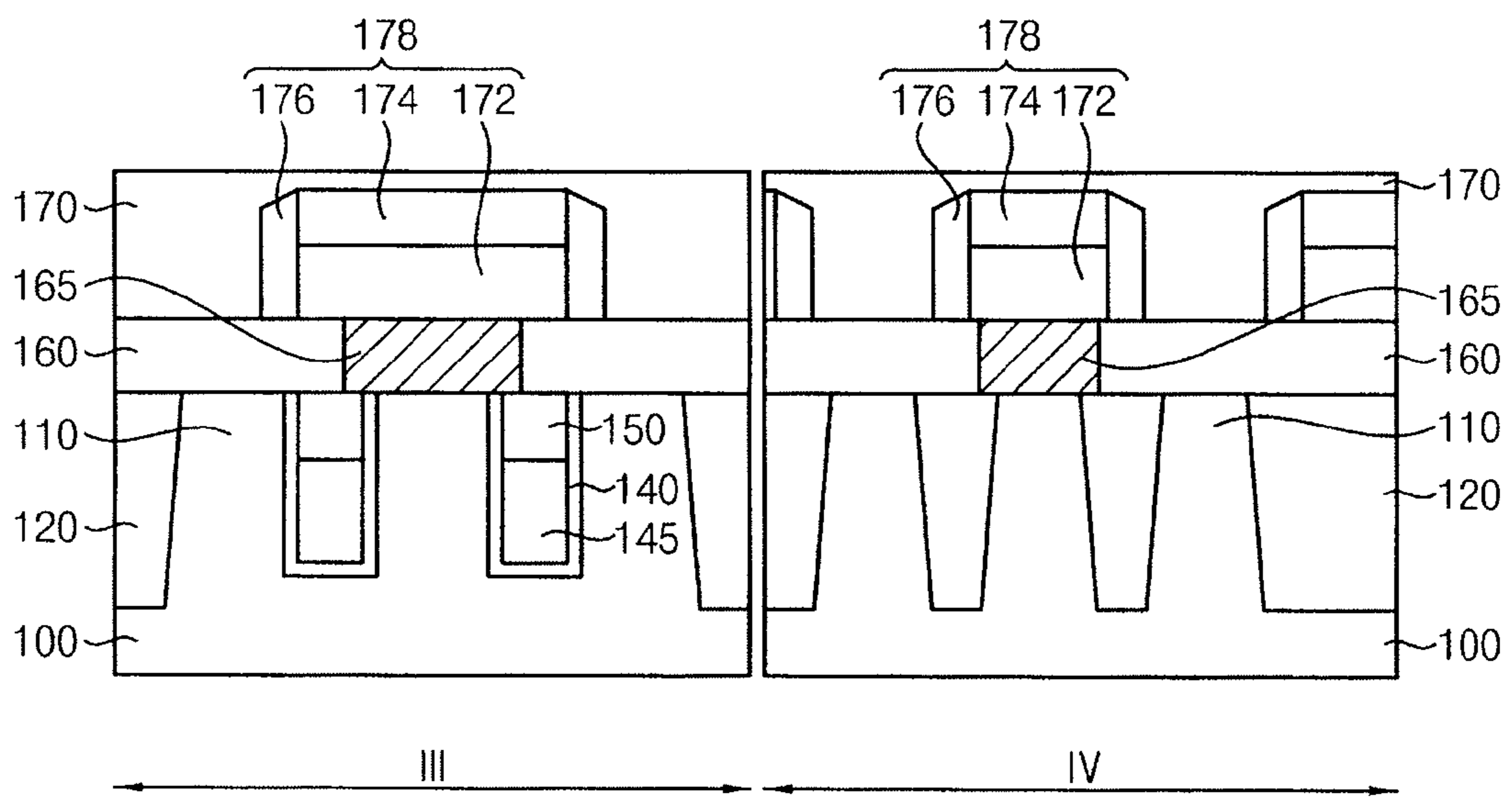


FIG. 7A

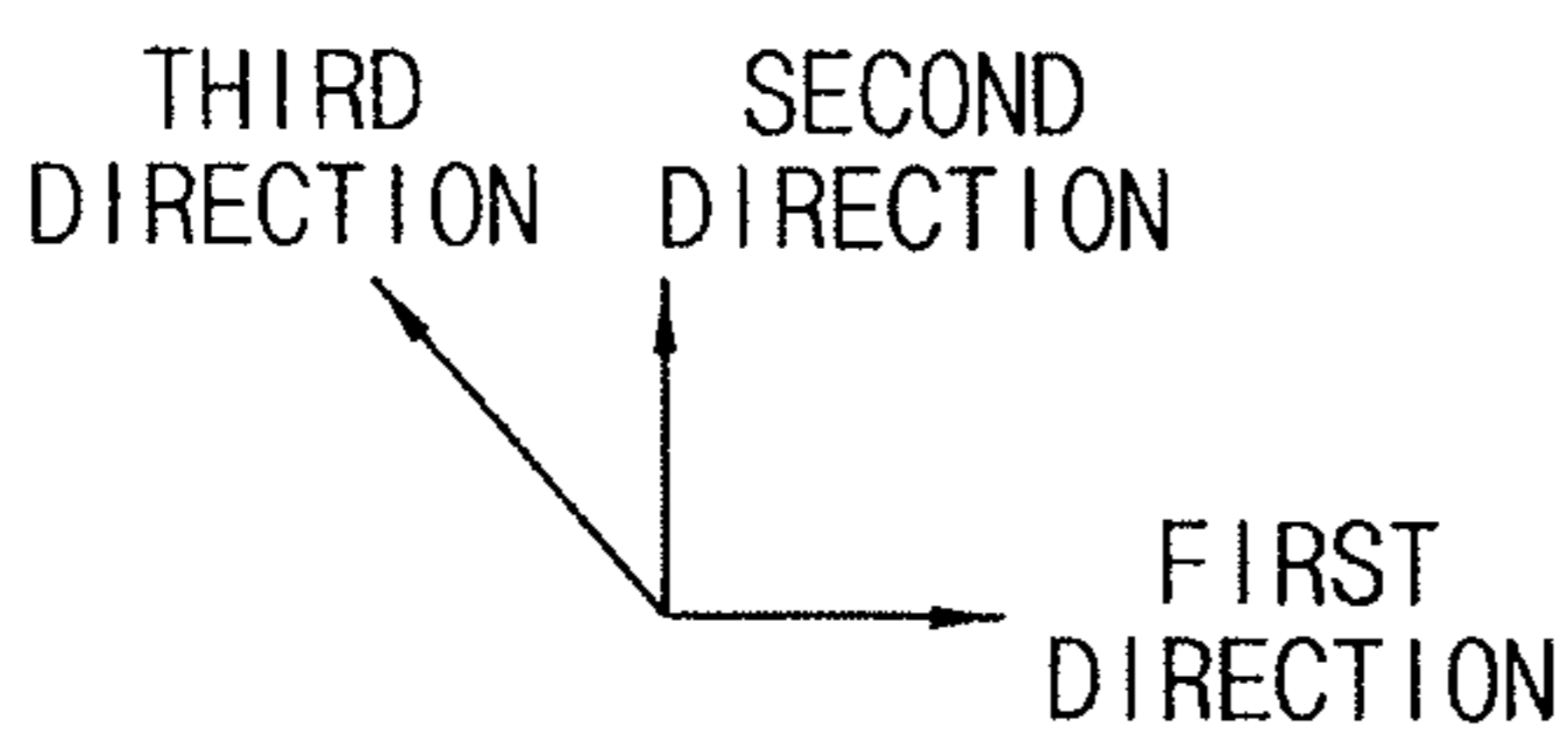
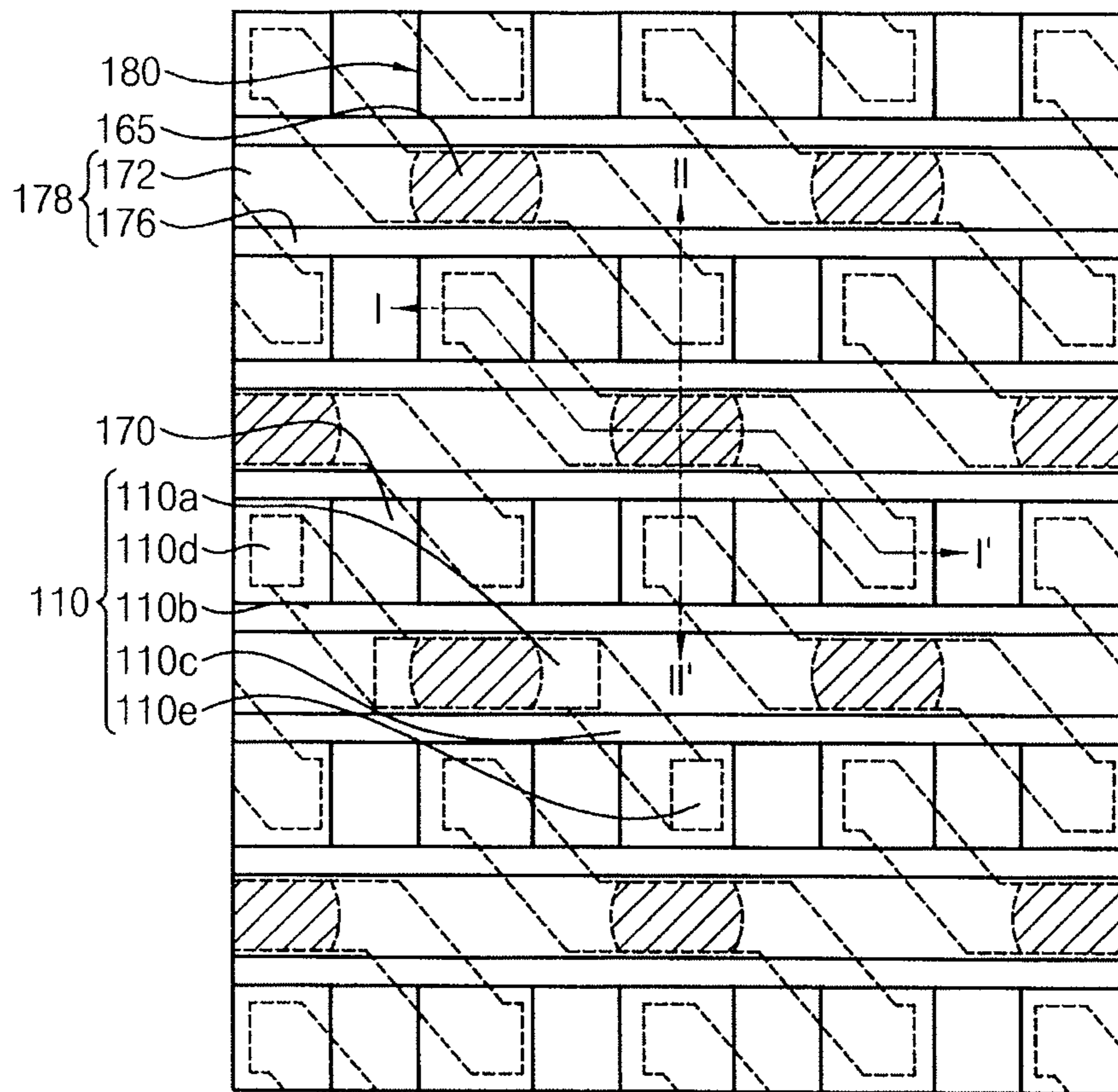


FIG. 7B

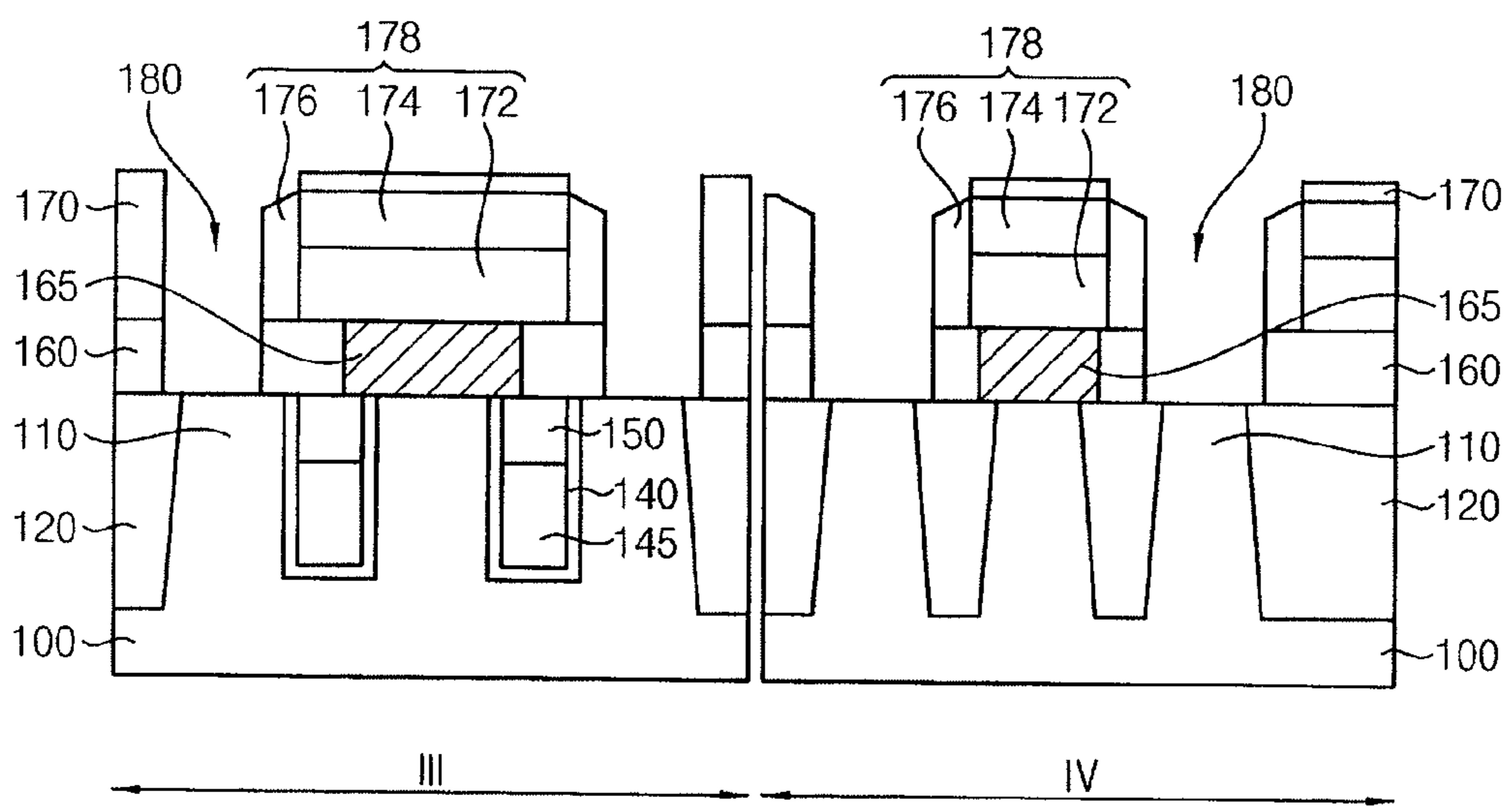


FIG. 8A

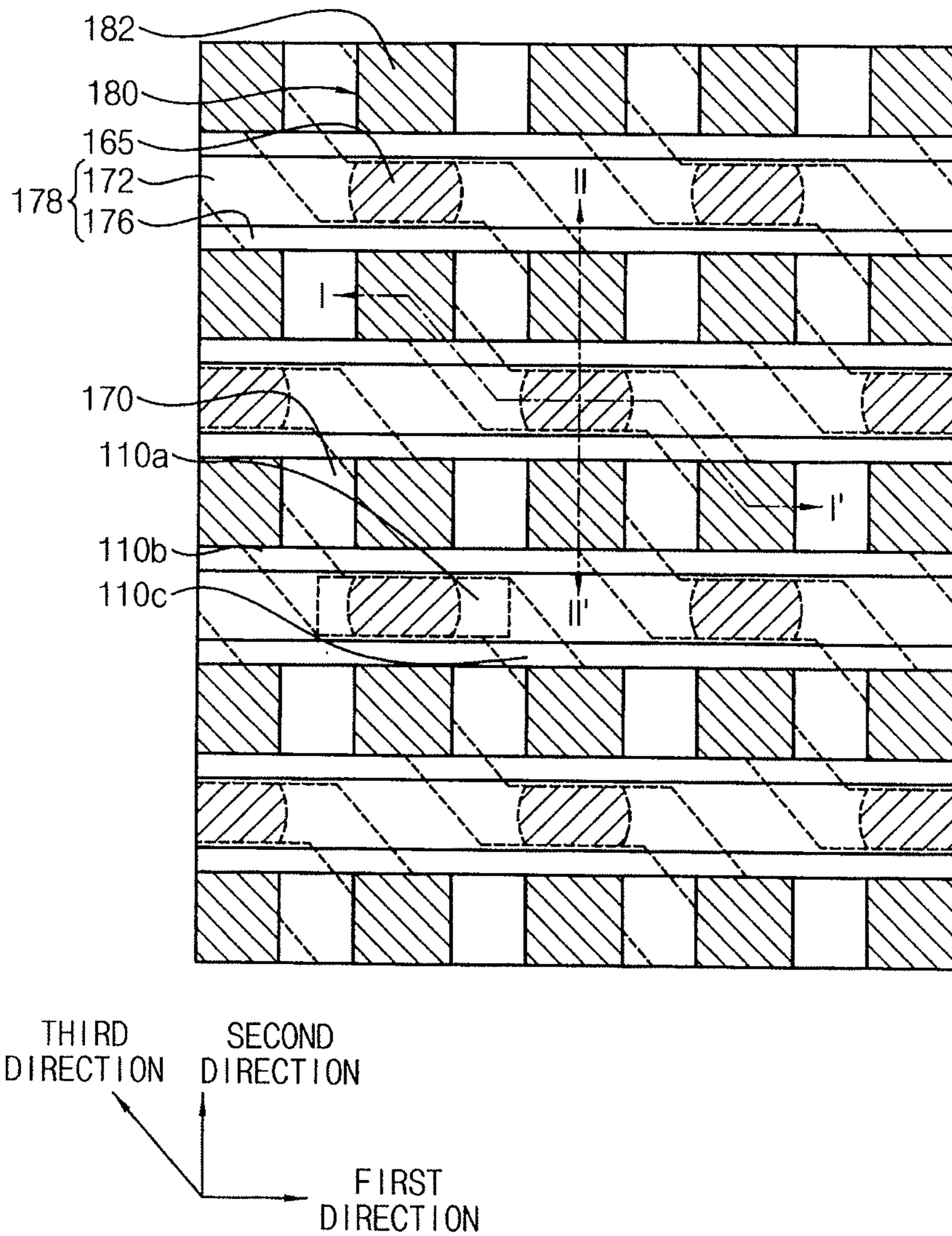


FIG. 8B

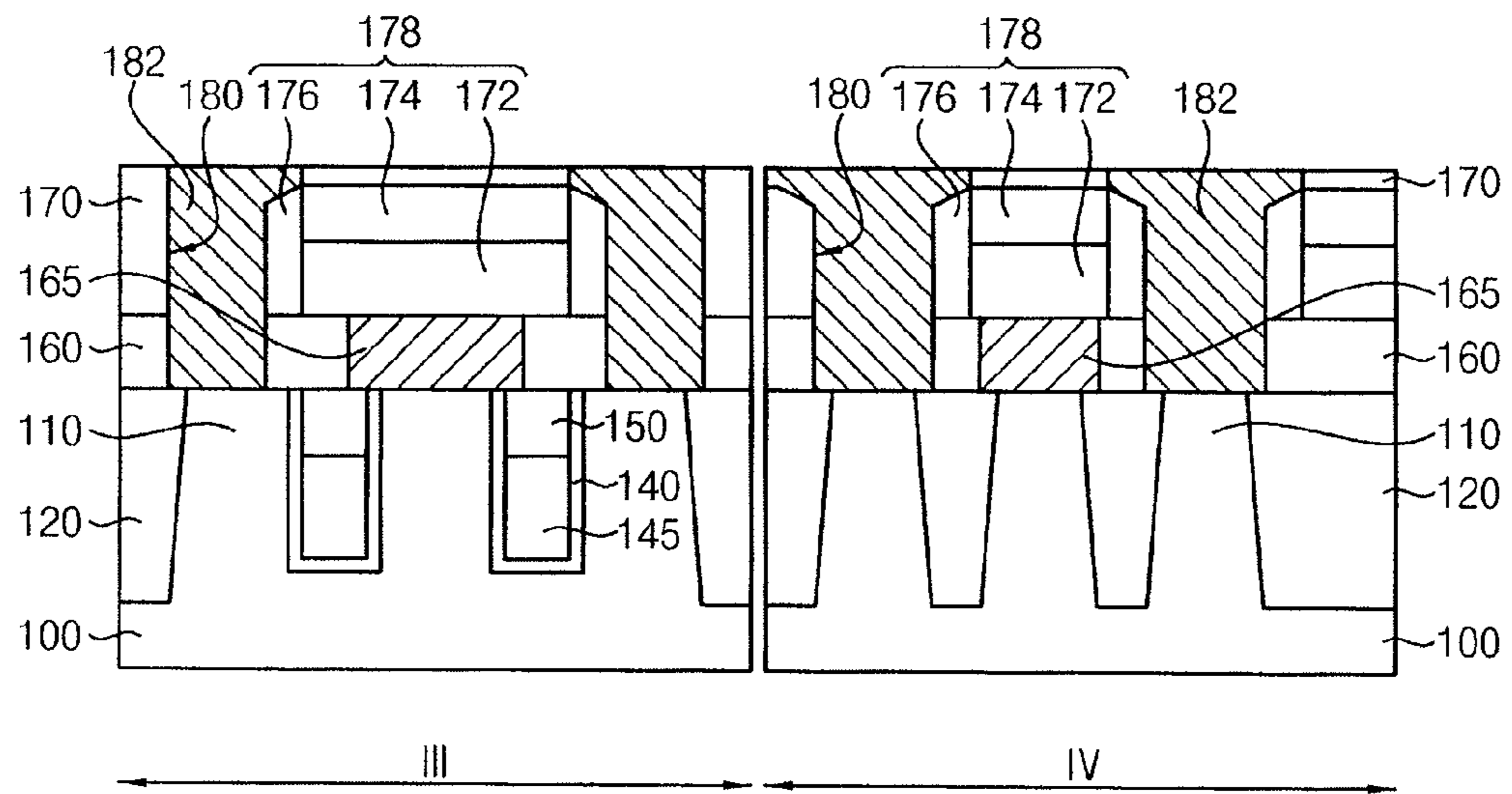


FIG. 9A

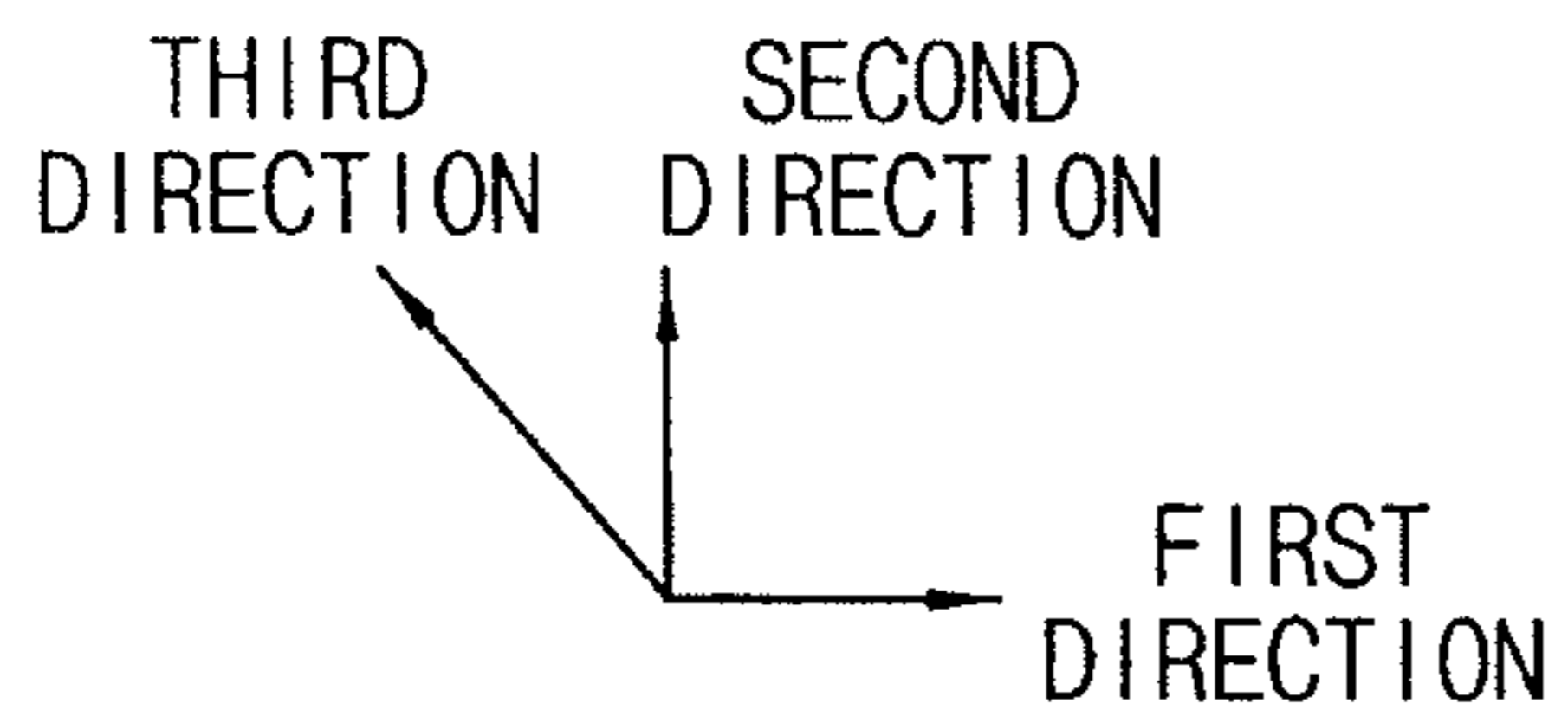
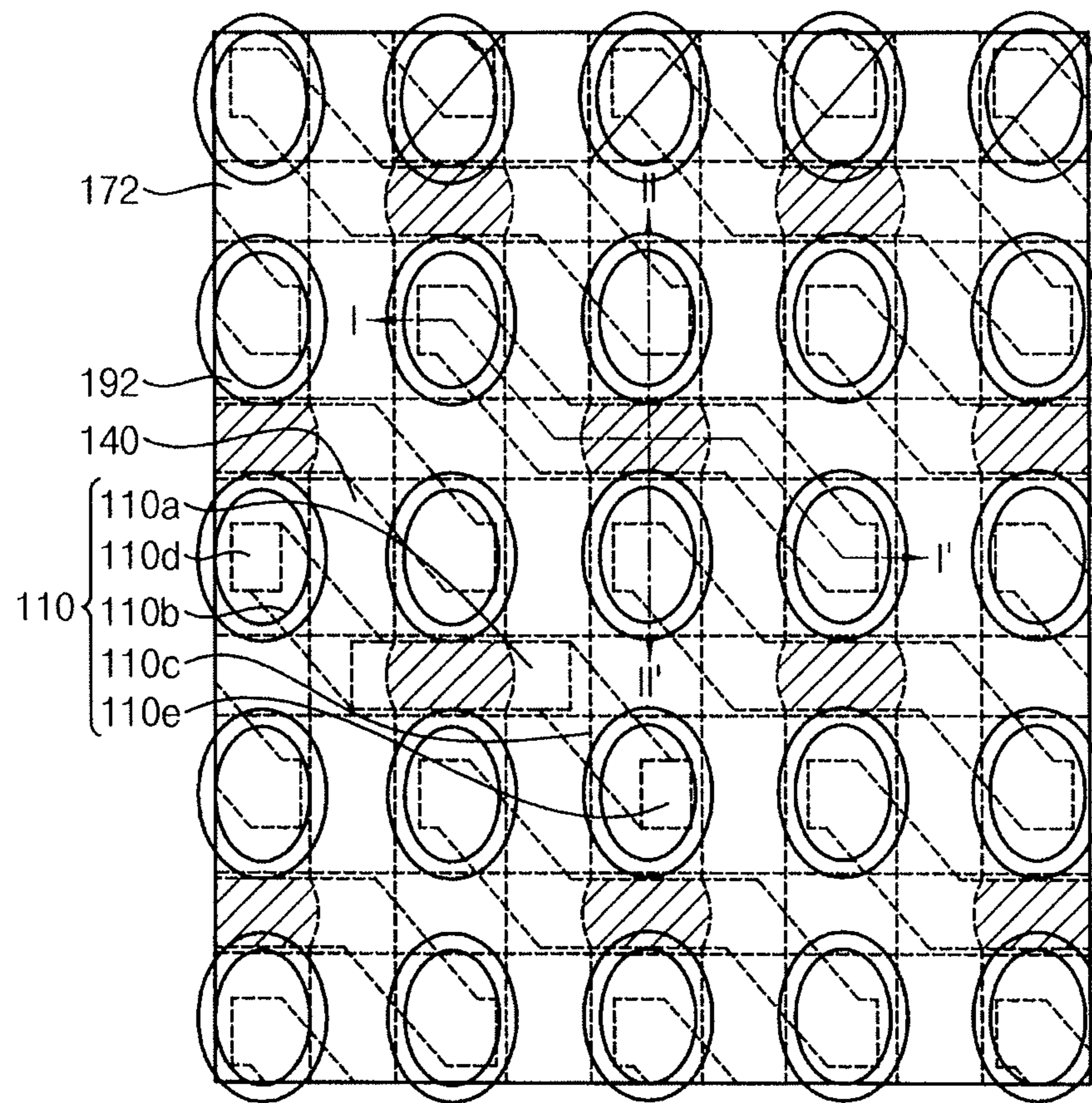


FIG. 9B

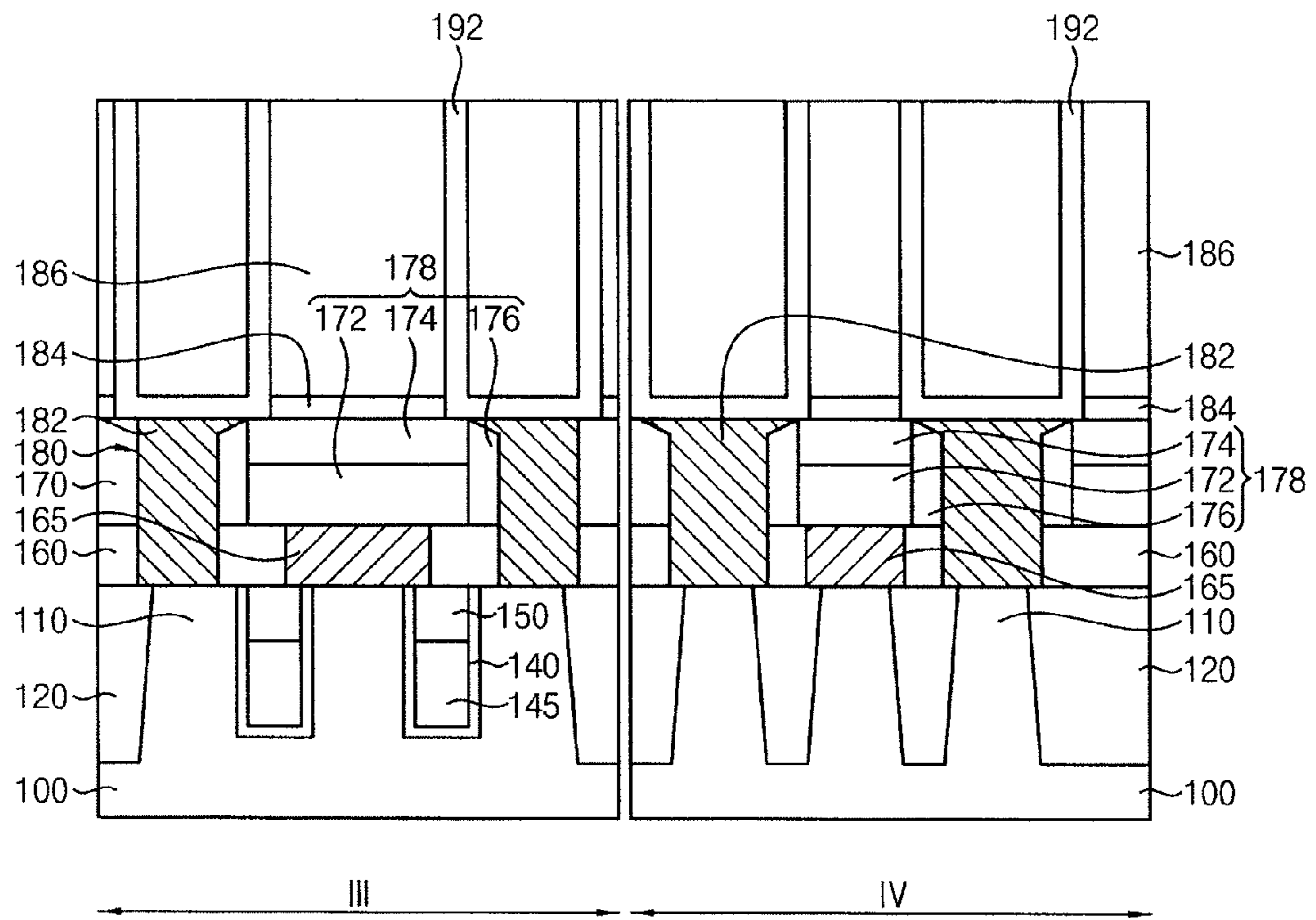


FIG. 10A

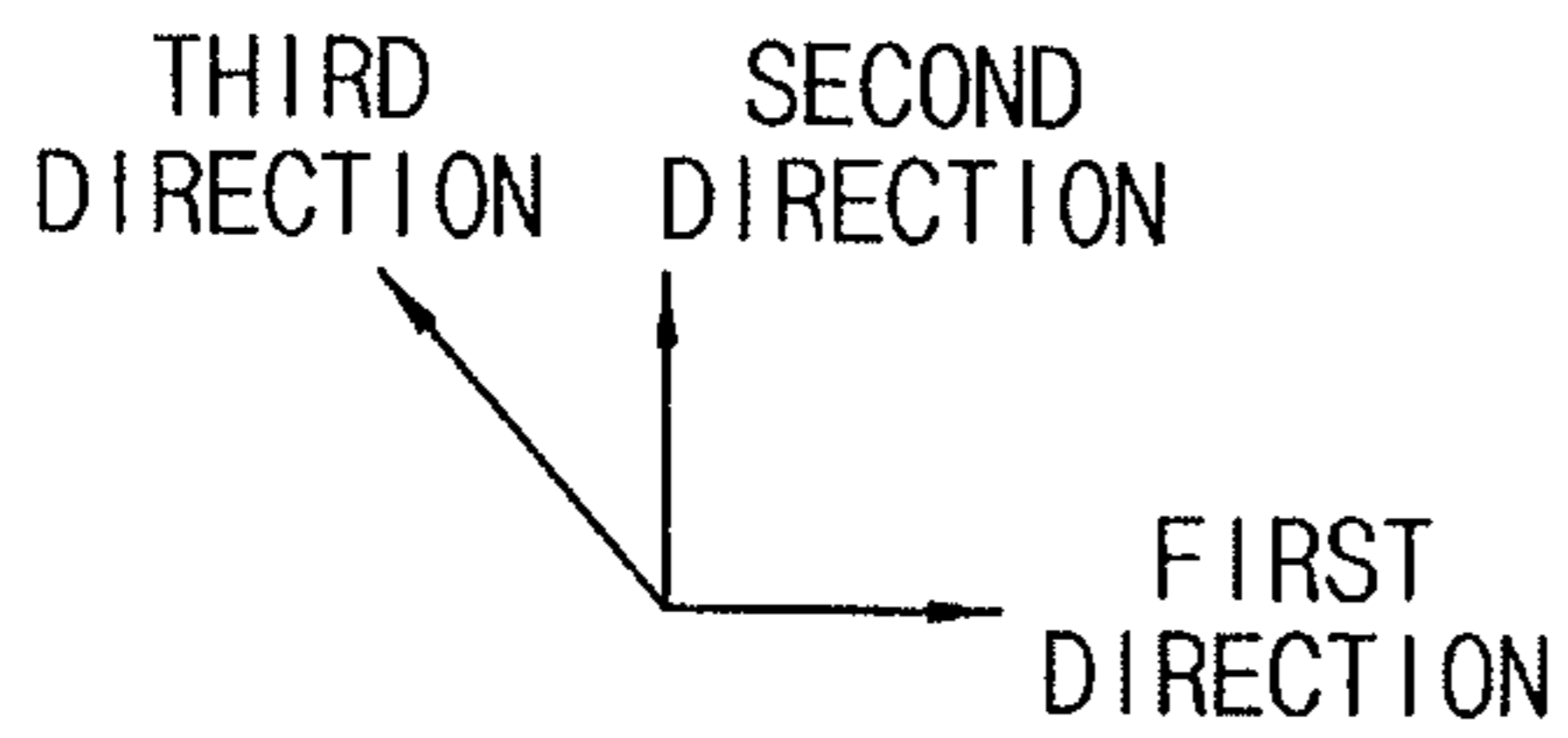
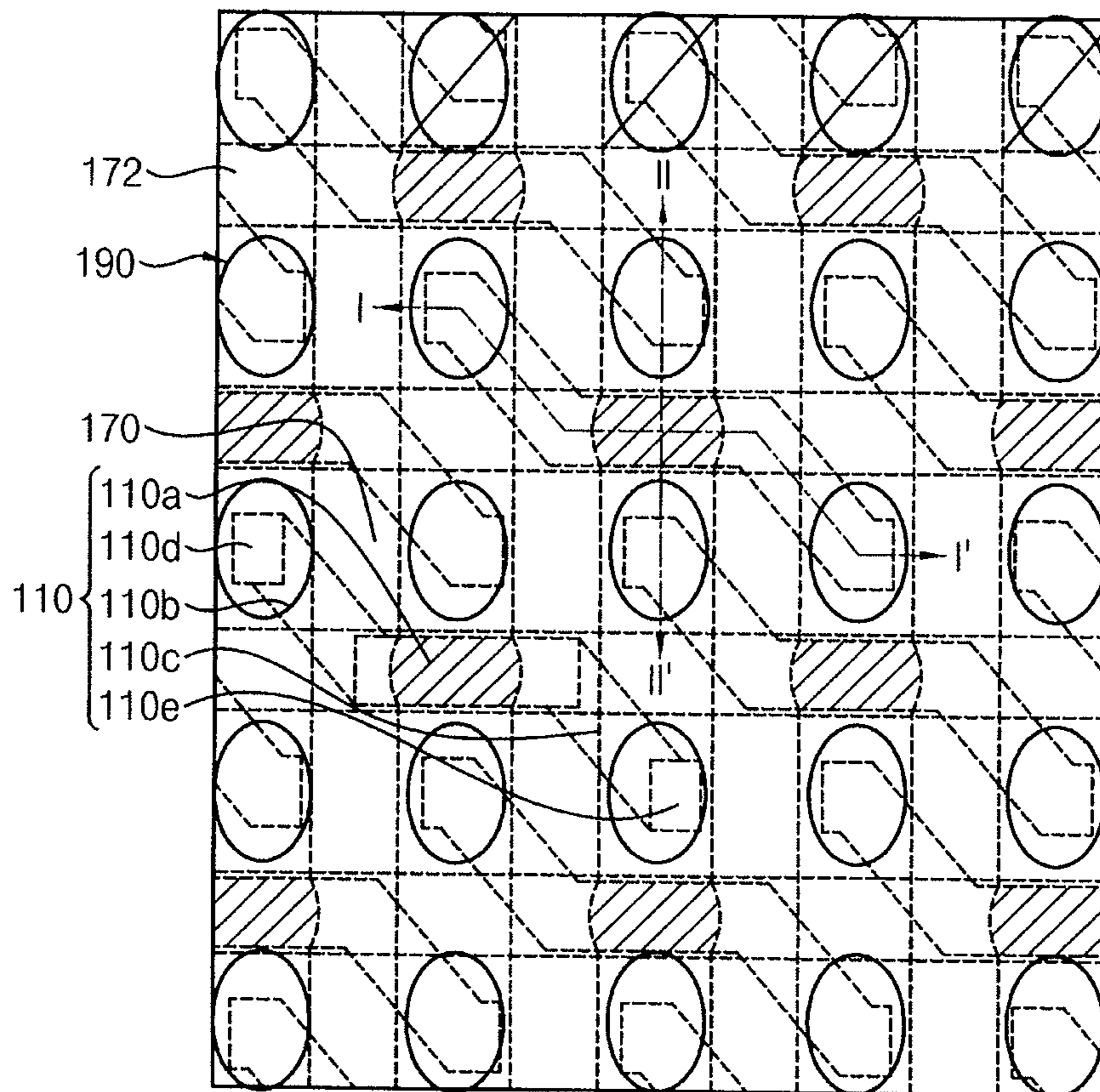


FIG. 10B

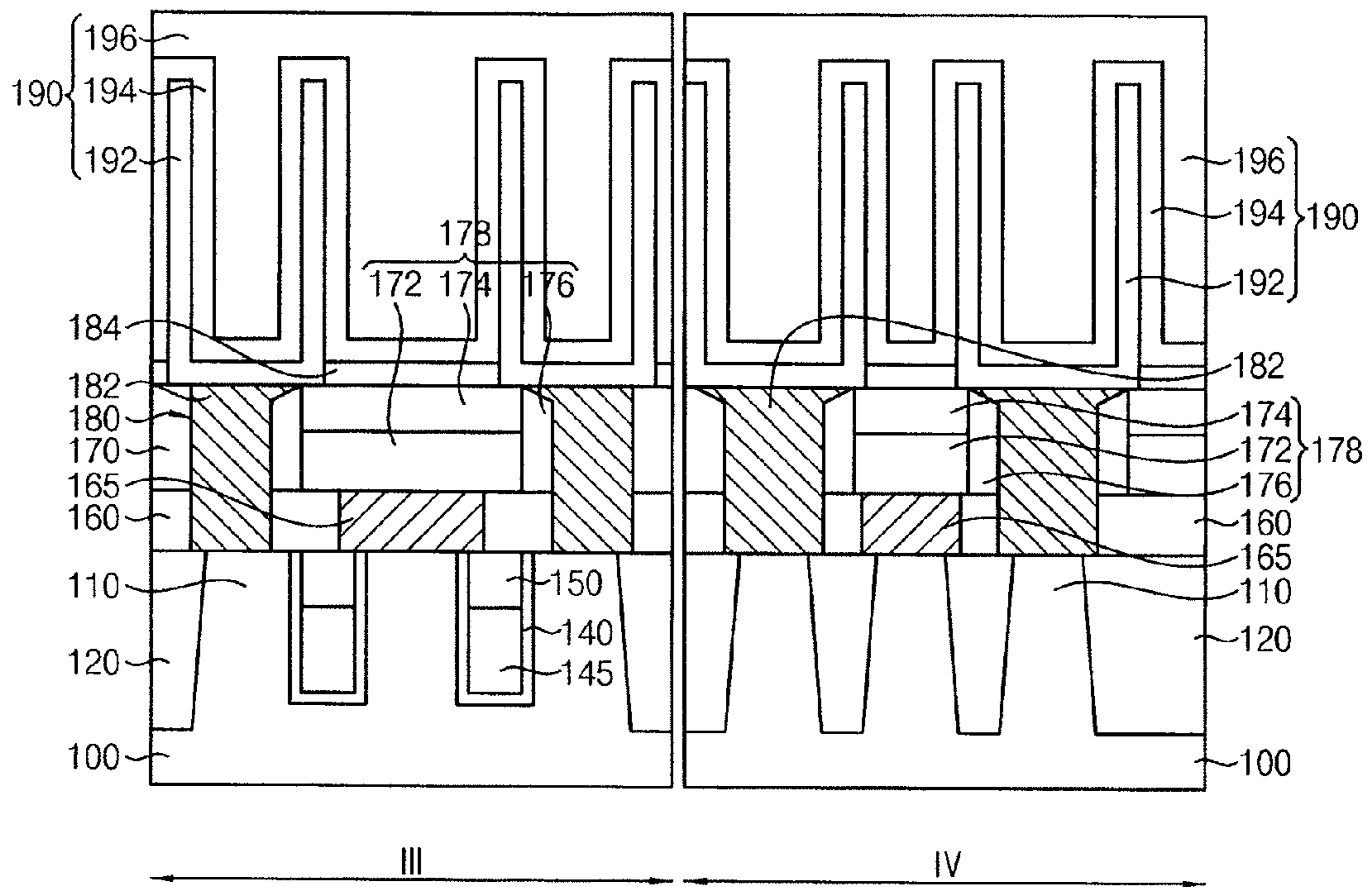


FIG. 11

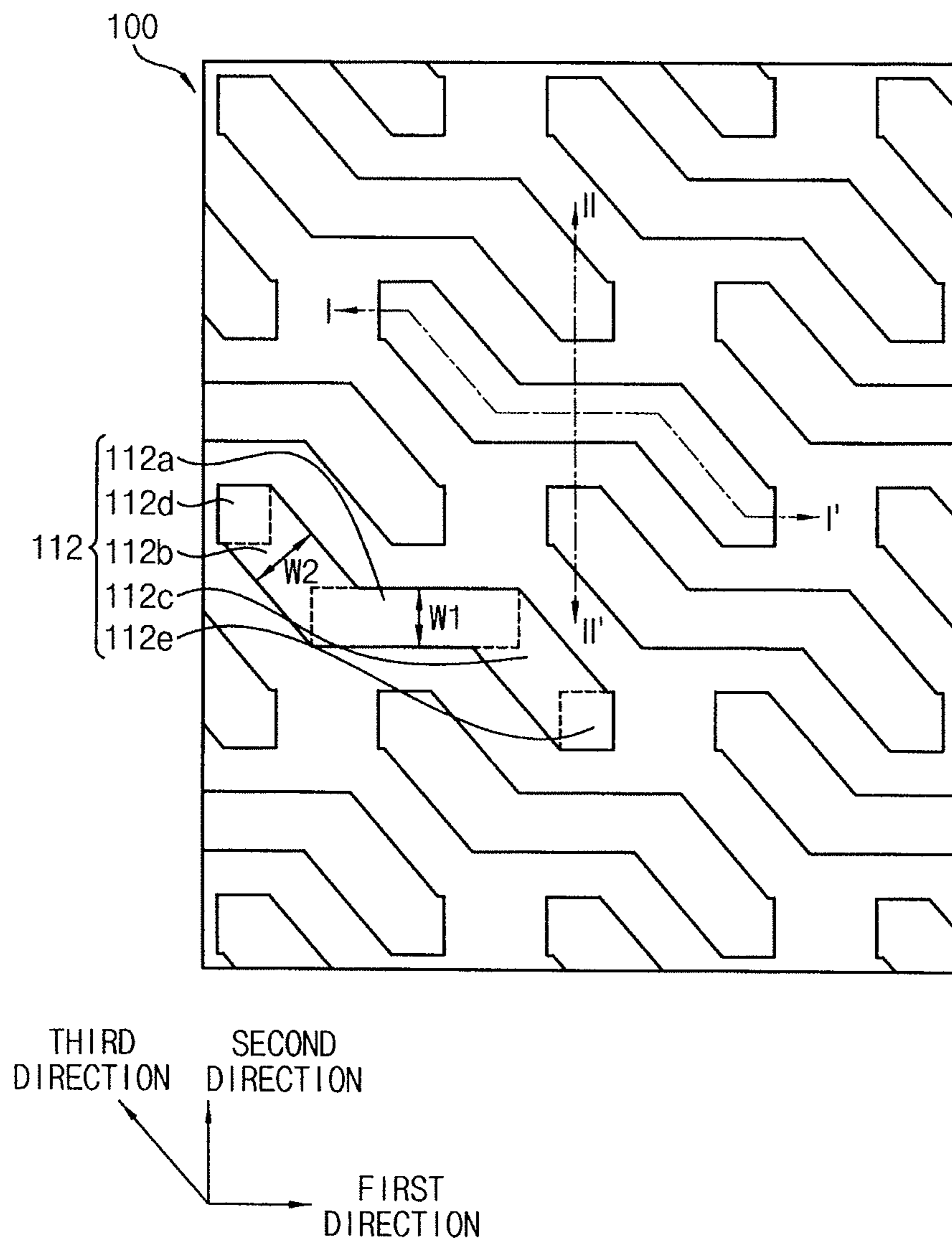


FIG. 12

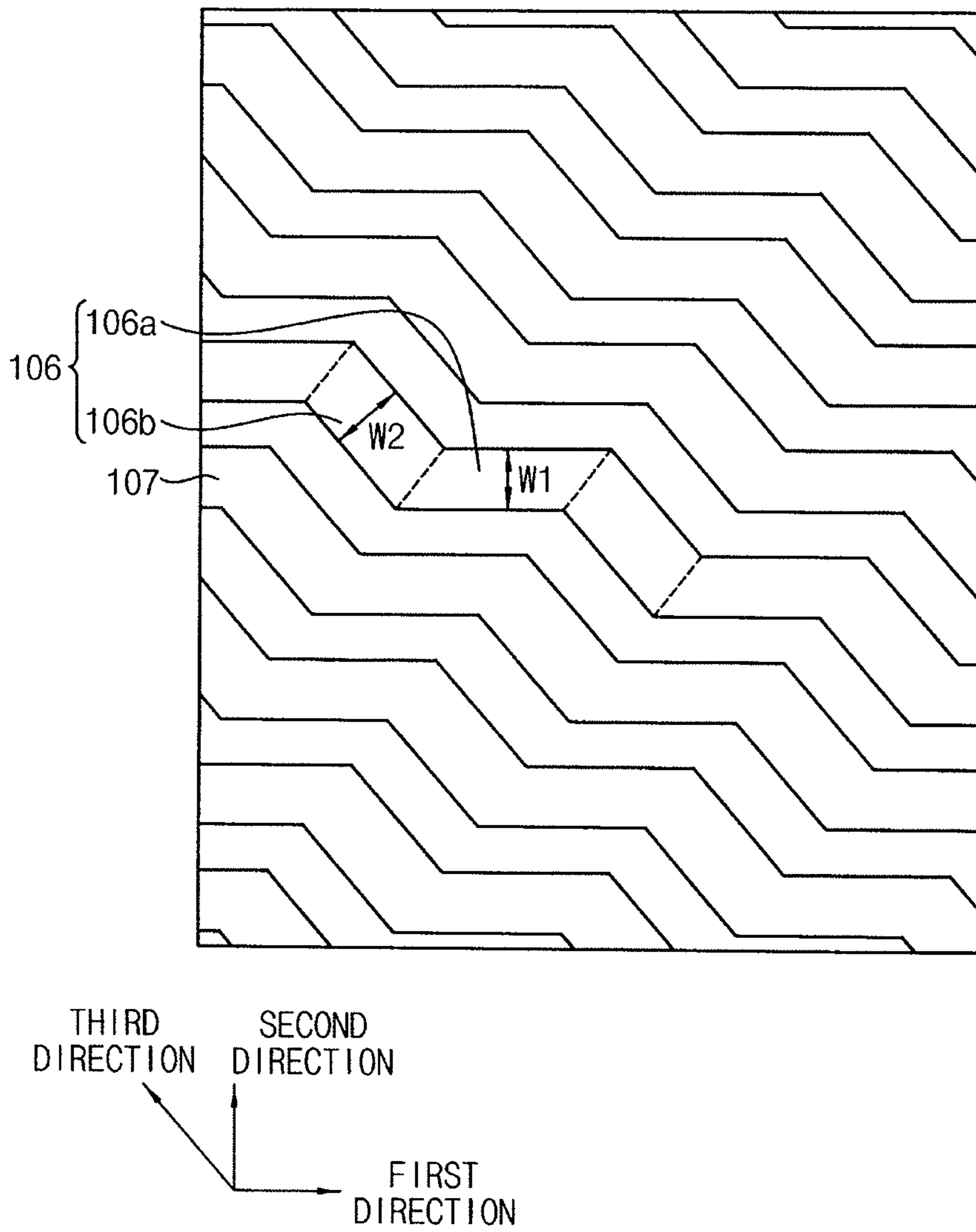


FIG. 13

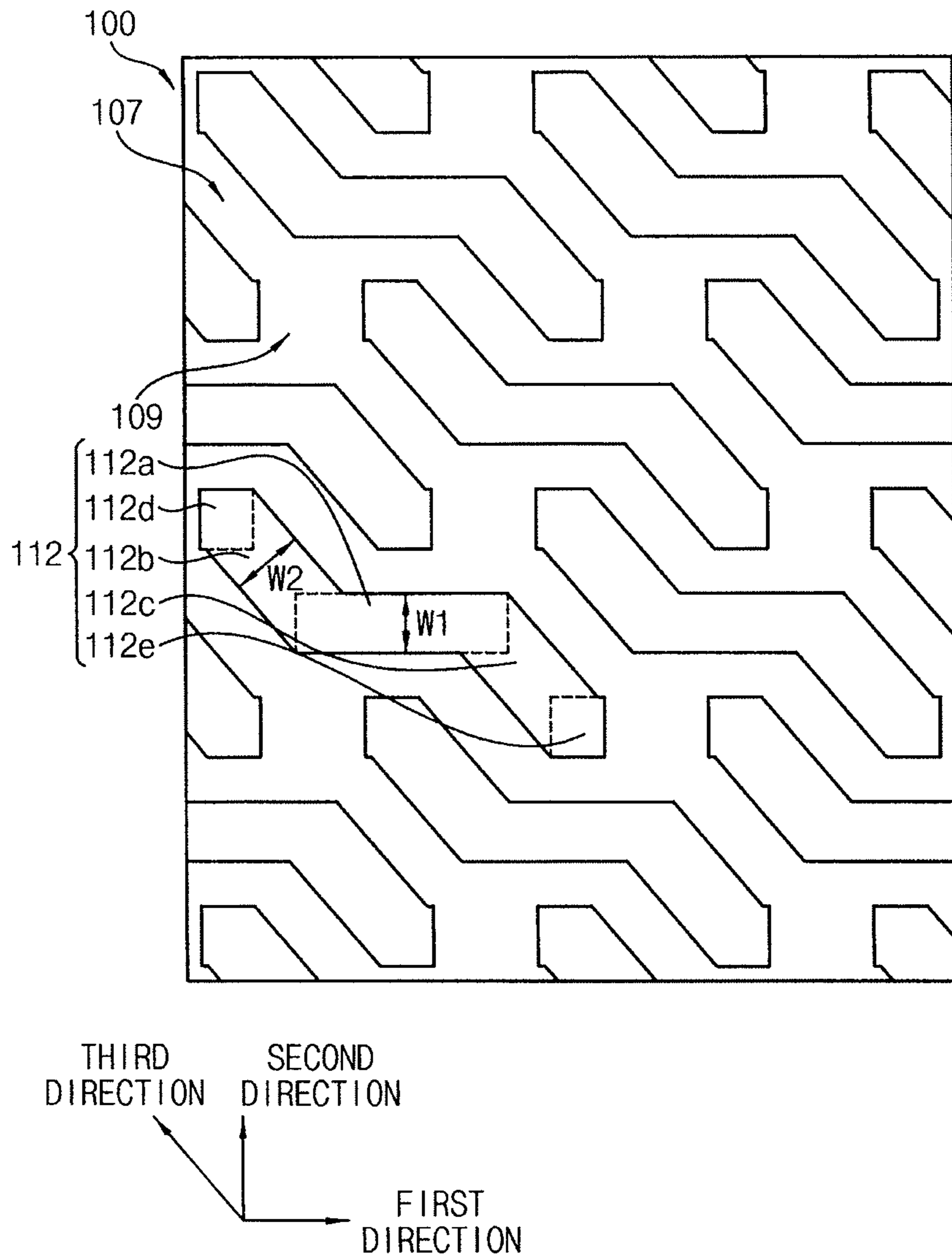


FIG. 14

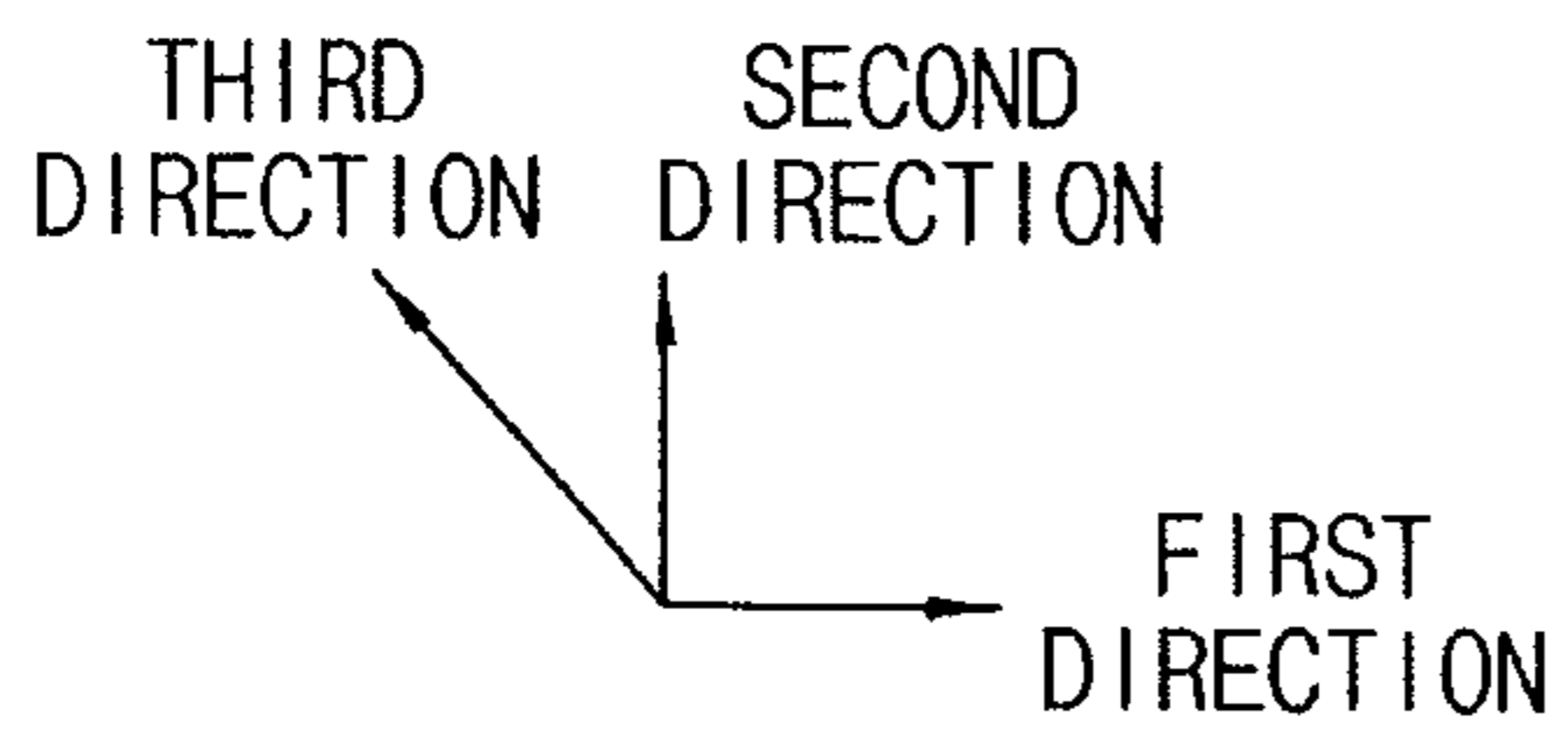
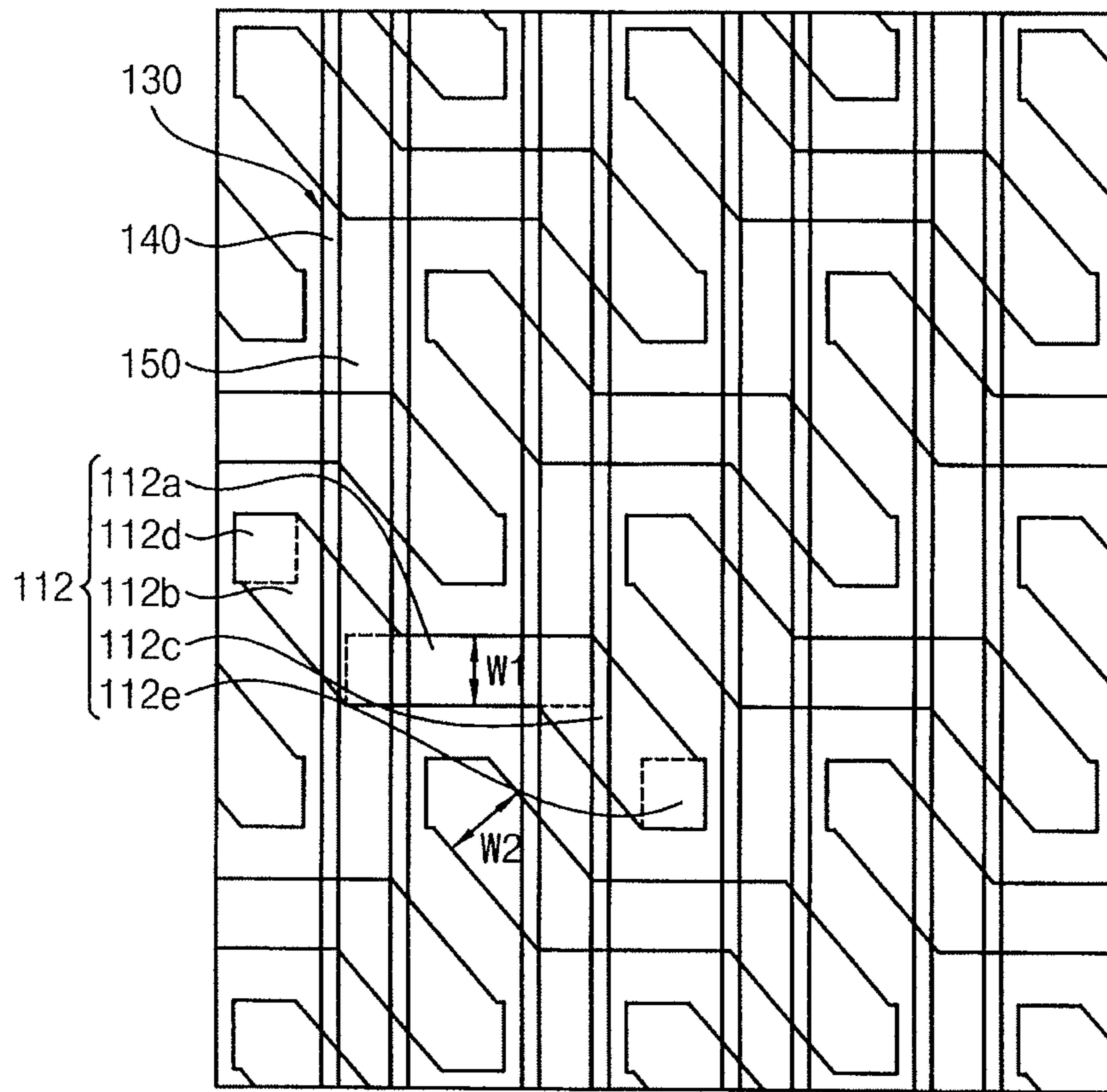


FIG. 15

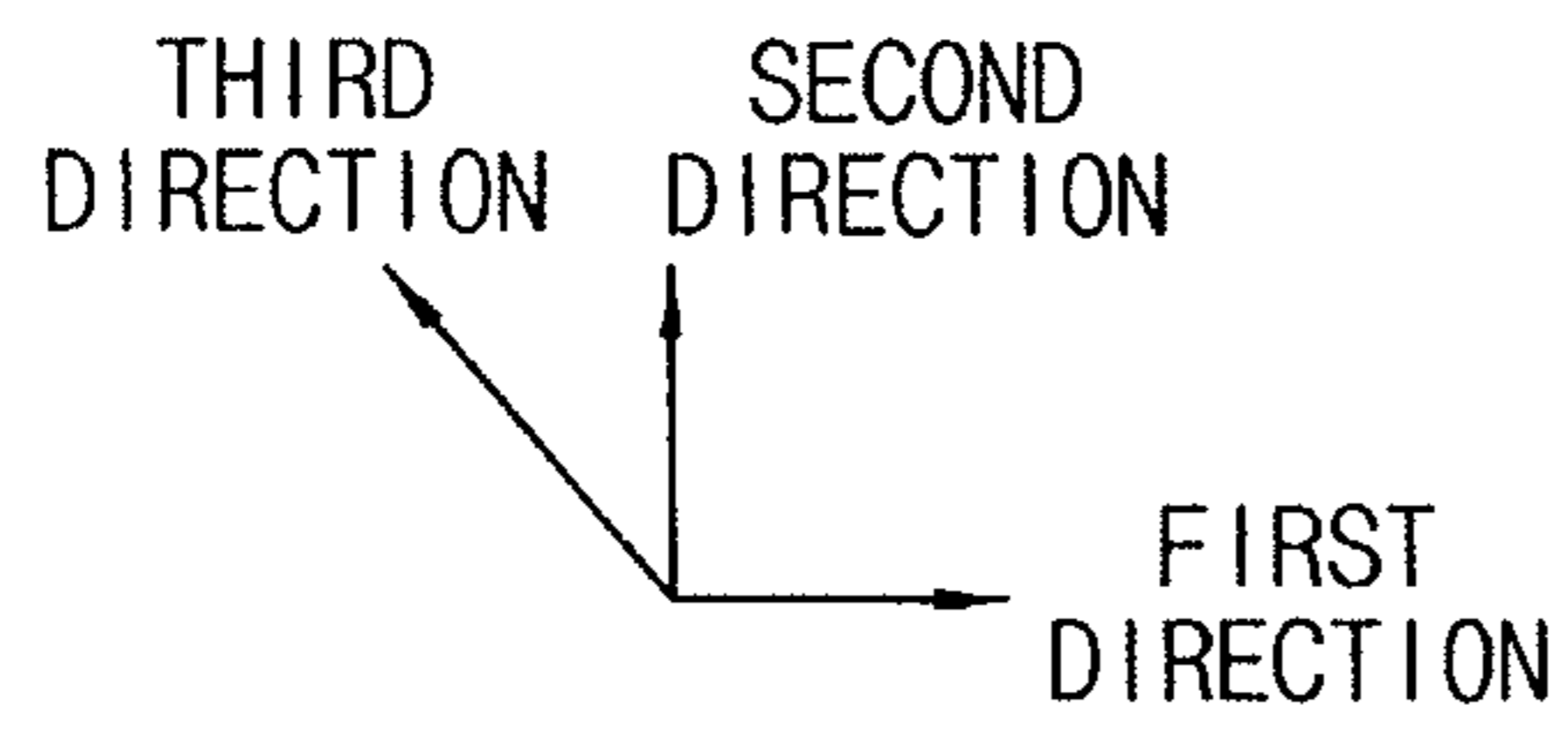
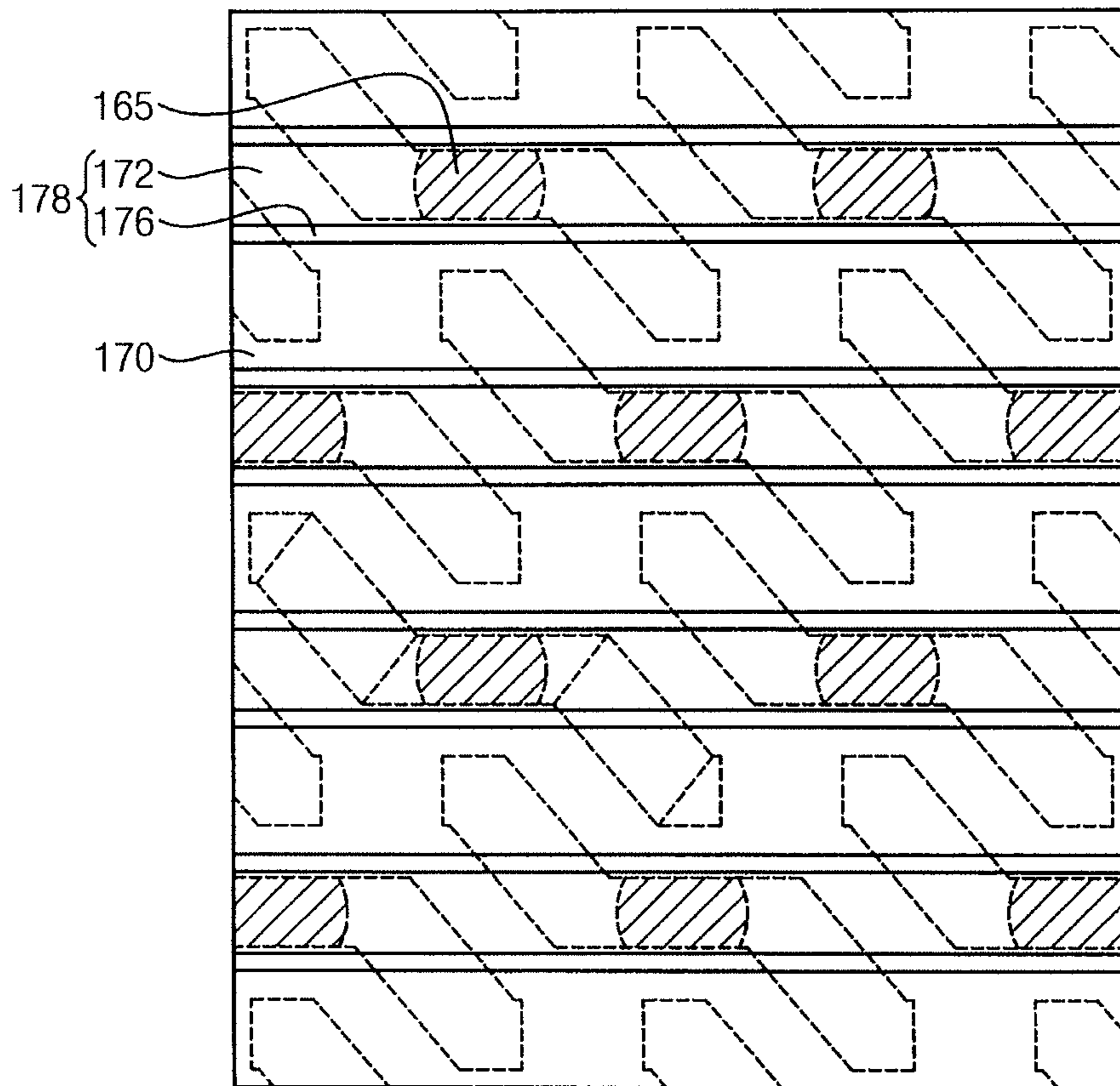


FIG. 16

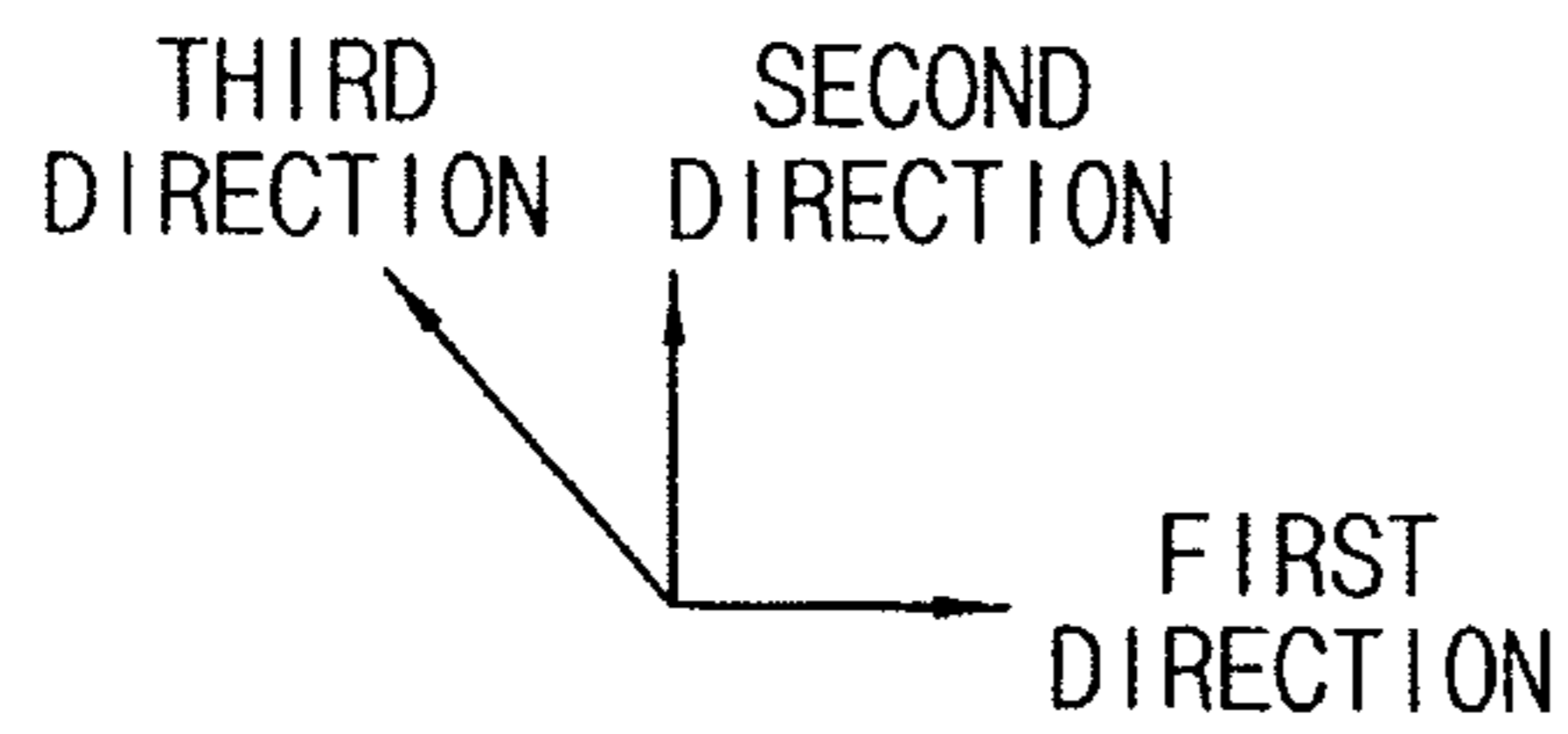
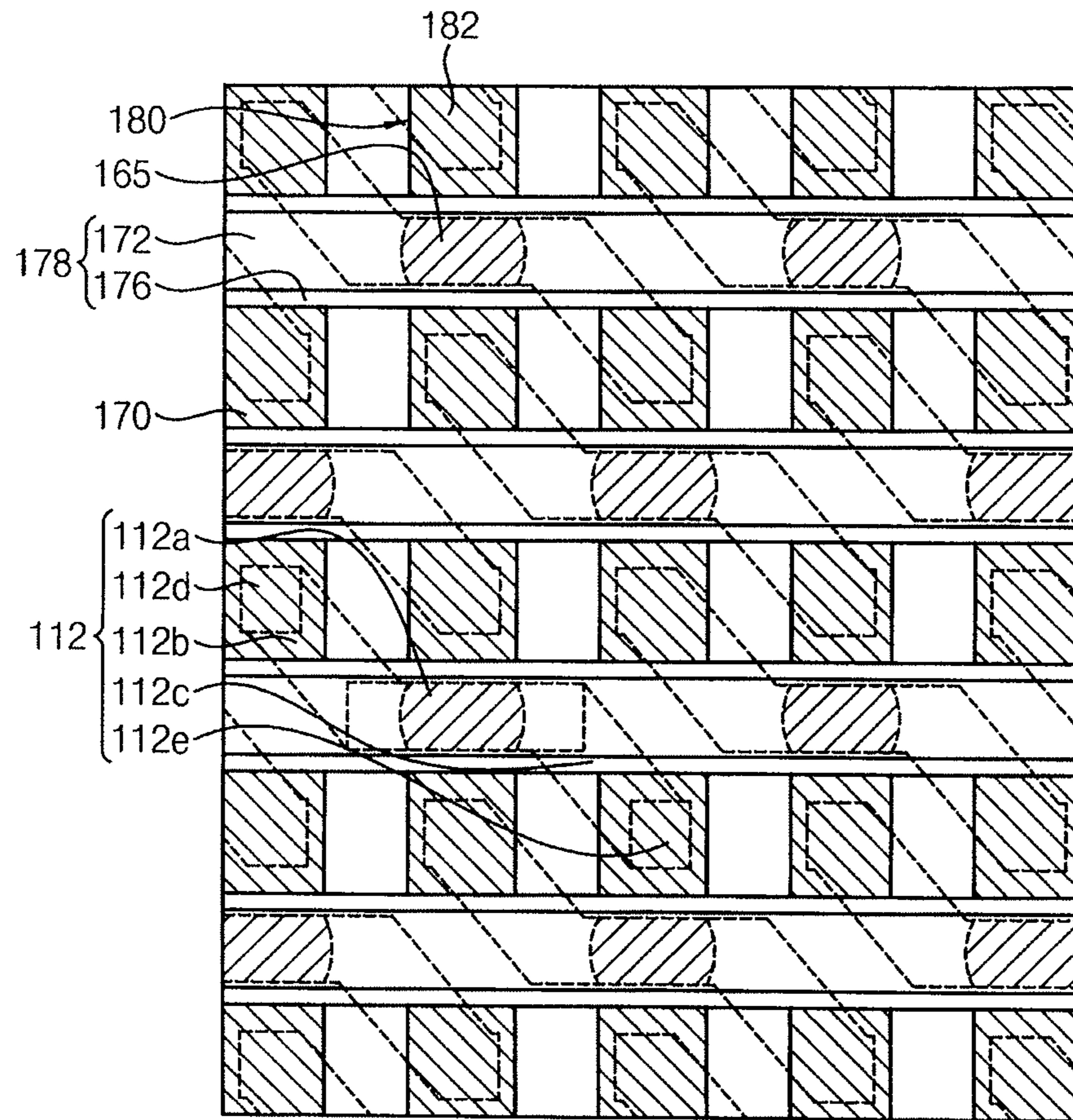


FIG. 17

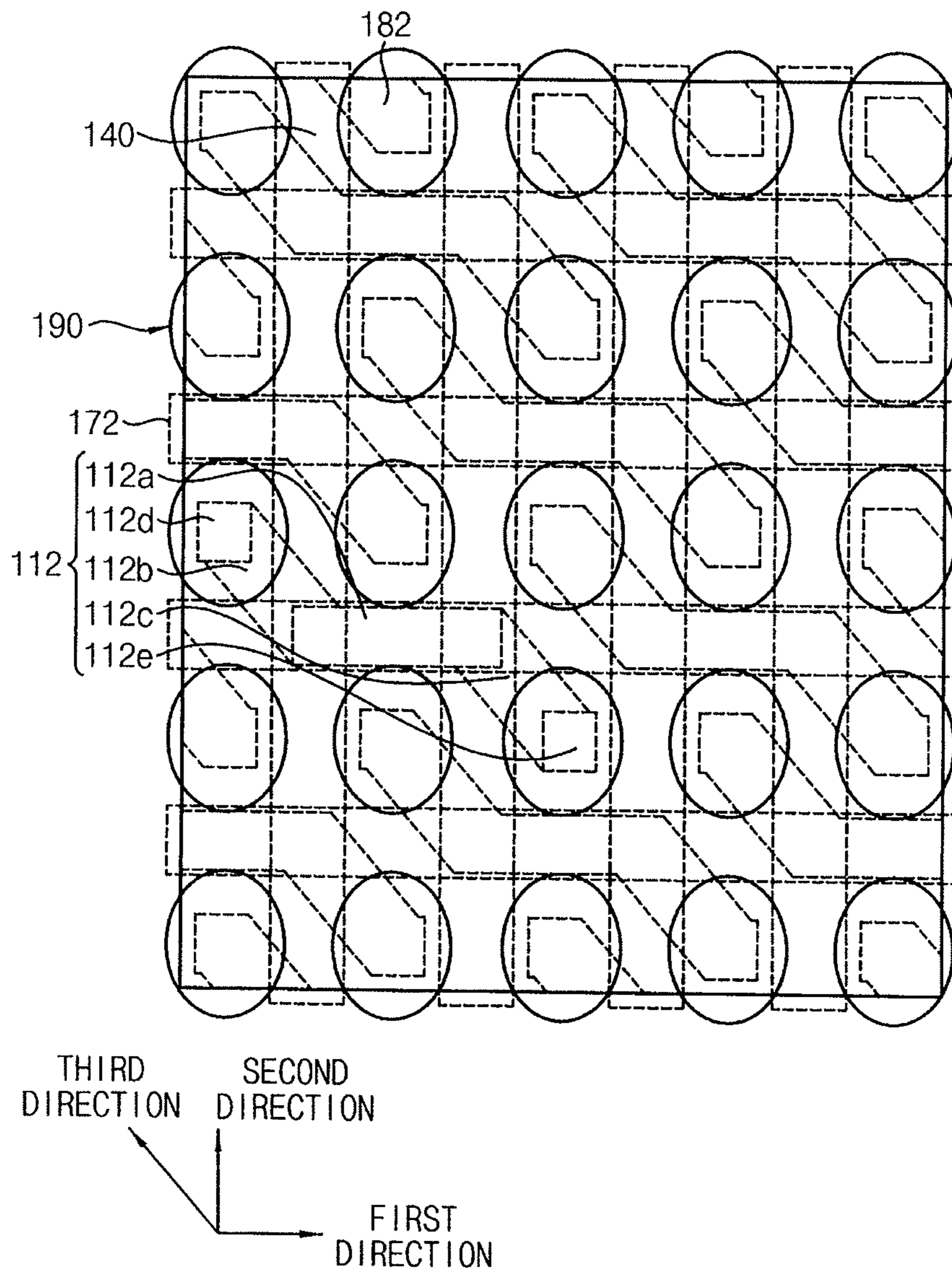
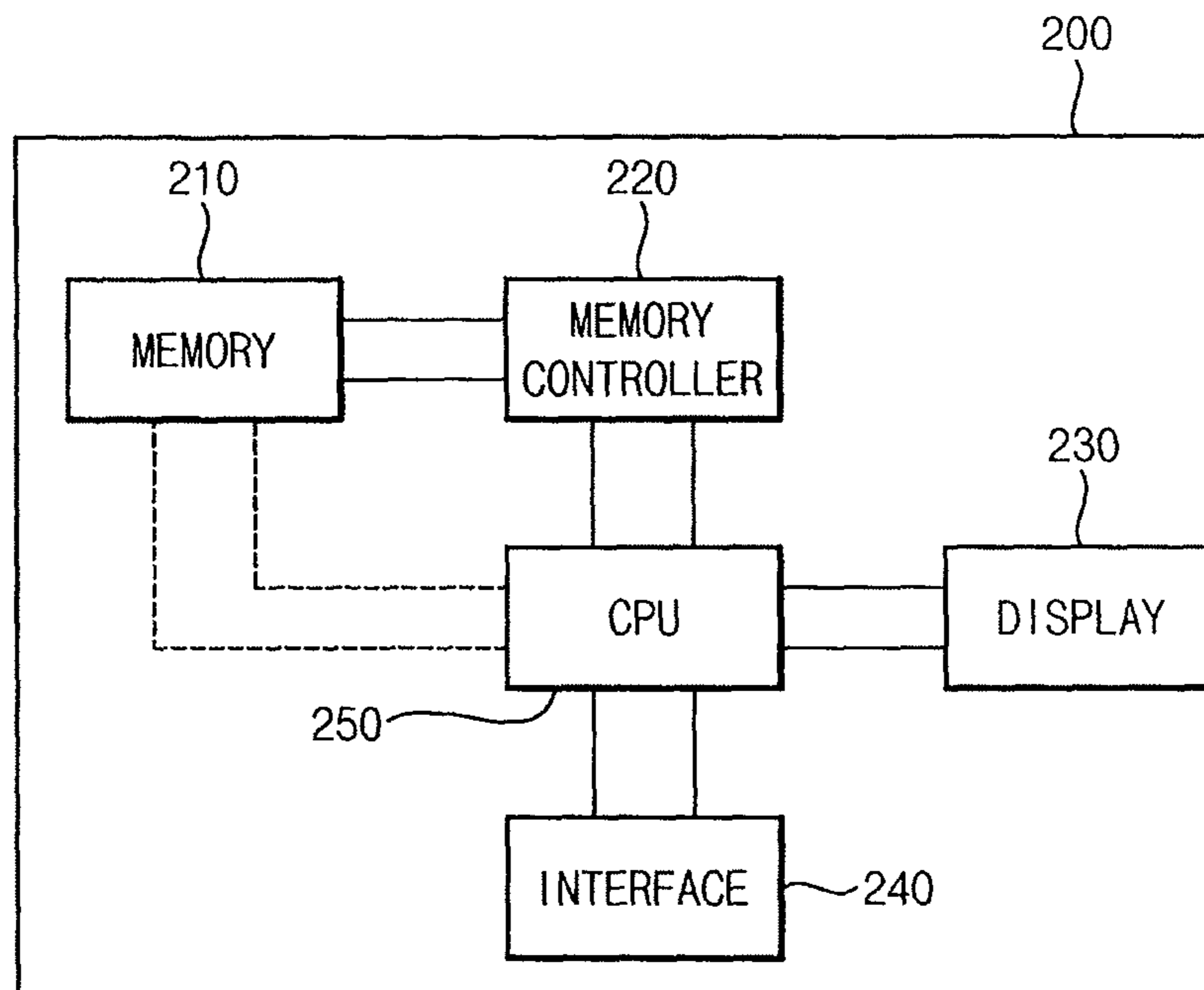


FIG. 18



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**SEMICONDUCTOR DEVICES AND
METHODS OF MANUFACTURING THE
SAME**

CROSS-REFERENCE TO RELATED
APPLICATION

Korean Patent Application No. 10-2013-0027696, filed on Mar. 15, 2013, in the Korean Intellectual Property Office, and entitled: "Semiconductor Devices and Methods of Manufacturing The Same," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

Example embodiments relate to semiconductor devices and methods of manufacturing the semiconductor devices.

2. Description of the Related Art

Recently, as the integration degree of a semiconductor device increases, a size of an active pattern has been decreased. Portions of the active pattern may be electrically connected to a bit line and/or a capacitor through contacts. However, as the size of the active pattern decreases, there are fewer process margins between the active pattern and the contacts.

SUMMARY

Example embodiments provide a semiconductor device including an active pattern with sufficient process margin to ensure reliability.

Example embodiments provide a method of manufacturing a semiconductor device including an active pattern with sufficient process margin to ensure reliability.

According to some example embodiments, there is provided a semiconductor device including a substrate. The substrate includes an active pattern surrounded by an isolation layer disposed at an upper portion of the substrate. The active pattern includes a first extension portion, a second extension portion, a third extension portion, a first projection portion and a second projection portion. The first extension portion extends in a first direction substantially parallel to a top surface of the substrate. The second extension portion extends from a first end of the first extension portion in a third direction oriented obliquely to the first direction. The third extension portion extends from a second end of the first extension portion in a direction opposed to the third direction. The first projection portion protrudes from the second extension portion in a direction opposed to the first direction. The first projection portion is spaced apart from the first extension portion. The second projection portion protrudes from the third extension portion in the first direction. The second projection portion is spaced apart from the first extension portion.

In example embodiments, the first projection portion and the second projection portion may be 180 degree rotationally symmetric about an axis passing through a center of the first extension portion in a fourth direction perpendicular to the first direction and the third direction, and the second extension portion and the third extension portion may be 180 degree rotationally symmetric about the axis.

In example embodiments, lengths of the first projection portion and the second projection portion in the first direction may be substantially smaller than a length of the first extension portion in the first direction.

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In example embodiments, a width of the first extension portion may be substantially the same as widths of the second extension portion and the third extension portion.

In example embodiments, a width of the first extension portion may be substantially smaller than widths of the second extension portion and the third extension portion.

In example embodiments, the semiconductor device may further comprise a bit line, a first contact, a capacitor and a second contact. The bit line extends in the first direction above the substrate. The first contact may connect the bit line with the first extension portion of the active pattern. The capacitor is disposed above the substrate. The second contact may connect the capacitor with the first projection portion or the second projection portion of the active pattern.

In example embodiments, a cross section of a region, where the first contact and the active pattern are overlapped, may have a rectangular shape or an elliptical shape extending in the first direction.

In example embodiments, a cross section of the second contact may have a rectangular shape extending in the first direction.

In example embodiments, a plurality of active patterns may be arranged in the first direction and the third direction.

According to some example embodiments, there is provided a method of manufacturing a semiconductor device. In the method, a trench is formed by removing an upper portion of a substrate, thereby defining an active pattern of the substrate. An isolation layer is formed to fill the trench. The active pattern includes a first extension portion, a second extension portion, a third extension portion, a first projection portion and a second projection portion. The first extension portion extends in a first direction substantially parallel to a top surface of the substrate. The second extension portion extends from a first end of the first extension portion in a third direction oriented obliquely to the first direction. The third extension portion extends from a second end of the first extension portion in a direction opposed to the third direction. The first projection portion protrudes from the second extension portion in a direction opposed to the first direction. The first projection portion is spaced apart from the first extension portion. The second projection portion protrudes from the third extension portion in the first direction. The second projection portion is spaced apart from the first extension portion.

In example embodiments, forming the trench may comprise forming a first trench extending in the first direction and the third direction alternately and repeatedly, thereby defining a preliminary active pattern and forming a second trench extending in a second direction perpendicular to the first direction. The second trench may be in fluid communication with the first trench.

In example embodiments, a first contact may be formed to directly contact the first extension portion of the active pattern. A bit line extending in the first direction may be formed to be electrically connected to the first contact. A second contact may be formed to directly contact the first projection portion or the second projection portion of the active pattern. A capacitor may be formed to be electrically connected to the second contact.

In example embodiments, a bit line spacer is formed on a side wall of the bit line after forming the bit line.

In example embodiments, forming the second contact may comprise forming an insulating interlayer above the substrate to cover the bit line, forming a contact hole exposing the first projection portion or the second projection portion of the active pattern by removing the insulating interlayer and forming a conductive pattern to fill the contact hole.

In example embodiments, the contact hole may be disposed not to overlap the bit line or the bit line spacer, and the contact hole may have a rectangular shape extending in the first direction.

According to some example embodiments, there is provided a semiconductor device. The semiconductor device including a substrate including an active pattern surrounded by an isolation layer, the isolation layer being disposed at an upper portion of the substrate, wherein the active pattern includes a first extension portion extending in a first direction, a first projection portion parallel to and spaced apart from the first extension portion, a second projection portion parallel to and spaced apart from the first extension portion, a second extension portion connecting the first extension portion and the first projection portion, the second extension portion extending in a direction oriented obliquely to the first direction, and a third extension portion connecting the first extension portion and the second projection portion, the second and third extension portions extending in opposite directions relatively to the first extension portion and being parallel to each other.

In example embodiments, the semiconductor device may further include a bit line extending in the first direction above the substrate, a first contact connecting the bit line with the first extension portion of the active pattern, a capacitor above the substrate, and a second contact connecting the capacitor with the first projection portion or the second projection portion of the active pattern.

In example embodiments, longitudinal directions of the first contact and the first extension portion may be parallel.

In example embodiments, an overlap region between the first contact and the first extension portion may be rectangular or elliptical, a major axis of the rectangular area or the elliptical areas extending in the first direction.

In example embodiments, longitudinal directions of the first contact, second contact, and the first extension portion may be parallel.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings. FIGS. 1 to 18 represent non-limiting, example embodiments as described herein.

FIG. 1 illustrates a plan view of a semiconductor device including an active pattern in accordance with some example embodiments;

FIGS. 2 to 10B illustrate plan views and cross-sectional views of stages in a method of manufacturing a semiconductor device in accordance with some example embodiments;

FIG. 11 illustrates a plan view of a semiconductor device including an active pattern in accordance with other example embodiments;

FIGS. 12 to 17 illustrate plan views of stages in a method of manufacturing a semiconductor device in accordance with other example embodiments;

FIG. 18 illustrates a block diagram of a system including a semiconductor device in accordance with example embodiments.

DETAILED DESCRIPTION

Various example embodiments will be described more fully hereinafter with reference to the accompanying drawings, in which some example embodiments are shown. Example embodiments may, however, be embodied in many different forms and should not be construed as limited to

those set forth herein. Rather, these example embodiments are provided so that this description will be thorough and complete, and will fully convey the scope of exemplary implementations to those skilled in the art. In the drawings, the sizes and relative sizes of layers and regions may be exaggerated for clarity.

It will be understood that when an element or layer is referred to as being “on,” “connected to” or “coupled to” another element or layer, it can be directly on, connected or coupled to the other element or layer or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly connected to” or “directly coupled to” another element or layer, there are no intervening elements or layers present. Like numerals refer to like elements throughout. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

It will also be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Example embodiments are described herein with reference to cross-sectional illustrations that are schematic illustrations of idealized example embodiments (and intermediate structures). As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, example embodiments should not be construed as limited to the particular shapes of regions illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, an implanted region illustrated as a rectangle will, typically, have rounded or curved features and/or a gradient of implant concentration at its edges rather than a binary change from implanted to non-implanted region. Likewise, a buried

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region formed by implantation may result in some implantation in the region between the buried region and the surface through which the implantation takes place. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the actual shape of a region of a device and are not intended to limit the scope of the example embodiments.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

Hereinafter, example embodiments will be explained in detail with reference to the accompanying drawings.

FIG. 1 illustrates a plan view of a semiconductor device including an active pattern in accordance with some example embodiments. Referring to FIG. 1, the semiconductor device may include a substrate **100** including an active pattern **110** and an isolation layer **120** surrounding the active pattern **110**.

The substrate **100** may include a semiconductor substrate, e.g., a silicon substrate, a germanium substrate, a silicon-germanium substrate, a silicon-on-insulator (SOI) substrate, or a germanium-on-insulator (GOI) substrate.

The isolation layer **120** may include an insulation material, e.g., silicon oxide. The isolation layer **120** may be disposed on the substrate **100**. In this case, an upper portion of the substrate **100** surrounded by the isolation layer **120** may be defined as the active pattern **110**. That is, the active pattern **110** may be integrally formed with the substrate **100**, and a sidewall of the active pattern **110** may be surrounded by the isolation layer **120**.

In example embodiments, a plurality of active patterns **110** may be arranged in a first direction substantially parallel to a top surface of the substrate **100** and a third direction oriented obliquely with respect to the first direction. Each of the active patterns **110** may include a plurality of extension portions extending in different directions. In example embodiments, the active pattern **110** may include a first extension portion **110a**, a second extension portion **110b**, a third extension portion **110c**, a first projection portion **110d**, and a second projection portion **110e** that are integral with each other and define a single active pattern **110**.

The first extension portion **110a** may extend in the first direction. The first extension portion **110a** may have a first width **W1** in a second direction substantially perpendicular to the first direction. The first extension portion **110a** may include a first end and a second end which may be spaced apart from each other in the first direction.

The second extension portion **110b** may extend from the first end of the first extension portion **110a** in the third direction, and the third extension portion **110c** may extend from the second end of the first extension portion **110a** in a direction opposed to the third direction. In this case, the second extension portion **110b** and the third extension portion **110c** may have substantially the same length and the same width. Accordingly, the second extension portion **110b** and the third extension portion **110c** may be 180 degree rotationally symmetric about an axis passing through a center of the first extension portion **110a**. In example embodiments, each of the second extension portion **110b** and the third extension portion **110c** may have a width substantially the same as the first width **W1** of the first extension portion **110a**.

Further, the first projection portion **110d** may protrude from the second extension portion **110b** in a direction

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opposed to the first direction, and the second projection portion **110e** may protrude from the third extension portion **110c** in the first direction. In this case, the first projection portion **110d** and the second projection portion **110e** may be spaced apart from the first extension portion **110a**. That is, the second extension portion **110b** may be disposed between the first extension portion **110a** and the first projection portion **110d**, and the third extension portion **110c** may be disposed between the first extension portion **110a** and the second projection portion **110e**.

In this case, the first projection portion **110d** and the second projection portion **110e** may have substantially the same length and the same width. Accordingly, the first projection portion **110d** and the second projection portion **110e** may be 180 degree rotationally symmetric about the axis passing through the center of the first extension portion **110a**. In example embodiments, each of the first projection portion **110d** and the second projection portion **110e** may have a length substantially smaller than that of the first extension portion **110a** in the first direction.

In example embodiments, the first projection portion **110d** and the second projection portion **110e** may have a rectangular planar shape, however embodiments are not be limited thereto. For example, the first projection portion **110d** and the second projection portion **110e** may have a circular shape or an elliptical planar shape.

According to example embodiments, the active pattern **110** may include the first extension portion **110a**, the first projection portion **110d**, and the second projection portion **110e** that may extend or protrude in the first direction. The first extension portion **110a**, the first projection portion **110d**, and the second projection portion **110e** may directly touch contacts that are electrically connected to a capacitor (see FIG. 10B) or a bit line (see FIG. 10B). The contacts may have a rectangular shape or an elliptical shape extending in the first direction, so that an overlapped area between the contacts and the active pattern **110** may increase. Therefore, a contact resistance between the contacts and the active pattern **110** may decrease, and the active pattern **110** may provide sufficient process margin to ensure reliability.

FIGS. 2 to 10B illustrate plan views and cross-sectional views of stages in a method of manufacturing a semiconductor device in accordance with some example embodiments. FIGS. 2, 3A, 4A, 5A, 6A, 7A, 8A, 9A and 10A illustrate plan views of stages in the method of manufacturing the semiconductor device in accordance with some example embodiments. FIGS. 3B, 4B, 5B, 6B, 7B, 8B, 9B and 10B illustrate cross-sectional views (III) along lines I-I' of FIGS. 3A, 4A, 5A, 6A, 7A, 8A, 9A and 10A and cross-sectional views (IV) along lines II-II' of FIGS. 3A, 4A, 5A, 6A, 7A, 8A, 9A and 10A.

Referring to FIG. 2, an upper portion of the substrate **100** may be removed to form a first trench **107**, thereby defining a preliminary active pattern **105**. The first trench **107** may be formed by forming a mask on the substrate **100**, and removing the upper portion of the substrate **100** using the mask as an etching mask. In example embodiments, a plurality of first trenches **107** may be arranged in a second direction substantially parallel to a top surface of the substrate **100**, and upper portions of the substrate between the first trenches **107** may be defined as the preliminary active pattern **105**.

In example embodiment, the first trench **107** may extend in a first direction substantially perpendicular to the second direction, and may extend in a third direction oriented obliquely to the first direction. Each of the first trenches **107** may include a plurality of first portions extending in the first direction and a plurality of second portions extending in the

third direction. That is, the plurality of first portions of the first trench **107** and the plurality of second portion of the first trench **107** may be arranged alternately and repeatedly, and the first portions and the second portions may be in fluid communication with each other.

Therefore, the preliminary pattern **105** may include first extension portion **105a** extending in the first direction and second extension portion **105b** extending in the third direction. Further, the first extension portion **105a** and the second extension portion **105b** may be arranged alternately and repeatedly. In example embodiment, the first extension portion **105a** may have the first width **W1** in the second direction, and the second extension portion **105b** may have a width substantially the same as that of the first extension portion **105a**.

Referring to FIG. 3A and FIG. 3B, an upper portion of the substrate **100** may be removed to form a second trench **109**, thereby defining an active pattern **110**. Then, an isolation layer **120** may be formed to fill the first trench **107** and the second trench **109**.

The second trench **109** may be formed by forming a mask on the substrate **100**, and removing the upper portion of the substrate **100** using the mask as an etching mask. In example embodiments, the second trench **109** may be disposed to partially overlap the first extension portion **105a** of the preliminary active pattern **105**. Therefore, some first extension portions **105a** of the preliminary active pattern **105** may be overlapped with the second trench **109**, and other first extension portions **105a** of the preliminary active pattern **105** may not be overlapped with the second trench **109**. The first trench **107** may be in fluid communication with the second trench **109**.

Therefore, the active pattern **110** may be defined by the first trench **107** and the second trench **109**. The active pattern **110** may include a plurality of extension portions extending in different directions. In example embodiments, the active pattern **110** may include the first extension portion **110a**, the second extension portion **110b**, the third extension portion **110c**, the first projection portion **110d**, and the second projection portion **110e**.

The first extension portion **110a** may extend in the first direction. The second extension portion **110b** may extend from a first end of the first extension portion **110a** in the third direction, and third extension portion **110c** may extend from a second end of the first extension portion **110a** in a direction opposed to the third direction. The first projection portion **110d** may protrude from the second extension portion **110b** in a direction opposed to the first direction, and the second projection portion **110e** may protrude from the third extension portion **110c** in the first direction. In this case, the first projection portion **110d** and the second projection portion **110e** may be spaced apart from the first extension portion **110a**.

Accordingly, the second extension portion **110b** and the third extension portion **110c** may be 180 degree rotationally symmetric about an axis passing through a center of the first extension portion **110a**, and the first projection portion **110d** and the second projection portion **110e** may be 180 degree rotationally symmetric about the axis.

In example embodiments, the first projection portion **110d** and the second projection portion **110e** may have a rectangular planar shape, however embodiments are not be limited thereto. For example, the first projection portion **110d** and the second projection portion **110e** may have a circular shape or an elliptical planar shape.

According to example embodiments, the first trench **107** and the second trench **109** may be formed by a multi-pattern-

ing process, instead of a single patterning process, due to the limited resolution of the optical patterning, i.e., via a photolithographic process. Therefore, a manufacturing process margin may be guaranteed, e.g., as compared to formation of the first trench **107** and the second trench **109** by a single patterning process.

Then, an insulation layer may be formed on the substrate **100** to fill the first trench **107** and the second trench **109**. Next, an upper portion of the insulation layer may be planarized until a top surface of the substrate **100** is exposed, thereby forming the isolation layer **120**. In example embodiments, the insulation layer may include, e.g., silicon oxide, silicon nitride, or silicon oxy-nitride.

Referring to FIG. 4A and FIG. 4B, upper portions of the substrate **100** and the isolation layer **120** may be removed to form a third trench **130**. Then, a gate insulation layer pattern **140**, a gate electrode **145**, and a gate mask **150** may be formed to fill the third trench **130**.

The third trench **130** may extend in the second direction. In example embodiments, a plurality of third trenches **130** may be arranged to be spaced apart from each other along the first direction. For example, a couple of third trenches **130** may be disposed to overlap a single active pattern **110**. For example, one third trench **130** may overlap an interface between the first extension portion **110a** and the second extension portion **110b**, e.g., a width of the third trench **130** along the first direction may overlap portions of and the interface between the first extension portion **110a** and the second extension portion **110b**, and another third trench **130** may overlap an interface between the first extension portion **110a** and the third extension portion **110c**, e.g., a width of the third trench **130** along the first direction may overlap portions of and the interface between the first extension portion **110a** and the third extension portion **110c**.

The gate insulation layer pattern **140** and the gate electrode **145** may be formed by forming a gate insulation layer and a gate electrode layer on the substrate **100** and the isolation layer **120** to fill the third trench **130**, and by planarizing upper portions of the gate insulation layer and the gate electrode layer by an etch back process or a CMP process. The gate electrode **145** may extend in the second direction, and may serve as a word line of the semiconductor device.

In example embodiment, the gate insulation layer may be formed by thermally oxidizing a surface of the substrate **100** exposed by the third trench **130**, or by performing a chemical vapor deposition (CVD) process or an atomic layer deposition (ALD) process using silicon oxide or a metal oxide. Further, the gate electrode layer may be formed using a metal or a metal nitride, e.g., tungsten (W), tantalum nitride (TaN), titanium nitride (TiN), and/or tungsten nitride (WN), by a physical vapor deposition process, an ALD process, or a sputtering process.

Then, the gate mask **150** may be formed on the gate electrode **145** to fill an upper portion of the third trench **130**. For example, the gate mask layer may be formed using silicon nitride or silicon oxy-nitride.

Therefore, a gate structure may be formed to include the gate insulation layer pattern **140**, the gate electrode **145**, and the gate mask **150**. The gate structure may include the gate electrode **145** buried at the upper portion of the substrate **100**, so that the gate structure may constitute a buried channel array transistor (BCAT).

Referring to FIG. 5A and FIG. 5B, a first insulating interlayer **160** may be formed on the substrate **100**, the isolation layer **120**, the gate mask **150**, and the gate insulation layer pattern **140**. A first contact **165** may be formed through the first insulating interlayer **160**.

In example embodiments, the first insulating interlayer **160** may be formed using silicon oxide, e.g., boro-phospho-silicate glass (BPSG), tonen silazene (TOSZ), undoped silicate glass (USG), spin on glass (SOG), flowable oxide (FOX), and/or tetra-ethyl-ortho-silicate (TEOS). Then, the first insulating interlayer **160** may be partially removed to form a first contact hole **163** exposing the first extension portion **110a** of the active pattern **110**. The first contact hole **163** may exposed the first extension portion **110a** of the active pattern **110**, the gate insulation layer pattern **140**, and the gate mask **150**.

The first contact **165** may be formed by forming a conductive layer on the first insulating interlayer **160** to fill the first contact hole **163**, and by planarizing an upper portion of the conductive layer until a top surface of the first insulating interlayer **160** is exposed. Therefore, the first contact **165** may directly contact the first extension portion **110a** of the active pattern **110**. In this case, a first contact area may be defined as an area where the first contact **165** and the active pattern **110** overlap. In example embodiments, the first contact **165** may include, e.g., doped polysilicon, a metal, or a metal nitride.

The first extension portion **110a** of the active pattern **110** extends in the first direction, so a cross section of the first contact area may have a rectangular shape or an elliptical shape extending in the first direction. In other words, as illustrated in FIG. 5A, longitudinal directions of the first extension portion **110a** and the first contact **165** extend in a same direction, so an overlap area between the first extension portion **110a** and the first contact **165** may have a rectangular shape or an elliptical shape extending in the first direction. Therefore, the size of the first contact area, i.e., an overlap area between the first extension portion **110a** and the first contact **165**, may increase. In contrast, when an active pattern, e.g., an entire active pattern, extends in a direction oblique to the first direction, a cross section of an overlap area between the active area and a contact area may have a parallelogram shape, i.e., a size of the first contact area may be smaller than a comparable overlap area having a rectangular shape or an elliptical shape.

According to example embodiments, as a size of the first contact area is increased, e.g., as compared to a contact area between a contact and an entire active pattern extending in a direction oblique to the first direction, a contact resistance between the first contact **165** and the active pattern **110** may decrease. Further, the active pattern **110** may provide sufficient process margin for forming the first contact **165** to ensure reliability and to prevent misalignment between the first contact **165** and the active pattern **110**.

Referring to FIG. 6A and FIG. 6B, a bit line **172**, a bit line mask **174**, and a bit line spacer **176** may be formed on the first insulating interlayer **160** and the first contact **165**.

The bit line **172** and the bit line mask **174** may be formed by forming a bit line layer and a bit line mask layer on the first insulating interlayer **160** and the first contact **165**, and by patterning the bit line layer and the bit line mask layer. In example embodiments, a plurality of bit lines **172** and a plurality of bit line masks **174** may be arranged in the second direction. Each of the bit lines **172** and the bit line masks **174** may extend in the first direction, so that the bit lines **172** may be parallel to the first extension portion **110a** of the active pattern **110**. The bit line **172** may be disposed to overlap the first extension portion **110a** of the active pattern **110**. The bit line mask layer may be formed using silicon nitride or silicon oxy-nitride.

Then, the bit line spacer **176** may be formed on sidewalls of the bit line **172** and the bit line mask **174**. The bit line spacer **176** may be formed by forming a spacer layer on the first insulating interlayer **160** and the first contact **165** to cover the

bit line **172** and the bit line mask **174**, and by anisotropically etching the spacer layer. Therefore, the bit line spacer **176** may extend in the first direction. For example, the bit line spacer **176** may include silicon nitride or silicon oxy-nitride. Therefore, a bit line structure **178** extending in the first direction may be formed to include the bit line **172**, the bit line mask **174** and the bit line spacer **176**.

Then, a second insulating interlayer **170** may be formed on the first insulating interlayer **160** and the first contact **165** to cover the bit line structure **178**. In example embodiments, the second insulating interlayer **170** may include a material substantially the same as or similar to that of the first insulating interlayer **160**.

Referring to FIG. 7A and FIG. 7B, the first insulating interlayer **160** and the second insulating interlayer **170** may be partially removed to form a second contact hole **180** exposing the active pattern **110**.

The second contact hole **180** may be formed by forming a mask on the second insulating interlayer **170** extending in the second direction, by removing the first insulating interlayer **160** and the second insulating interlayer **170** using the mask, the bit line spacer **176** and the bit line mask **174** as an etch mask. Therefore, the second contact hole **180** may be disposed not to overlap the mask, the bit line spacer **176** and the bit line mask **174**. The mask may extend in the second direction, and the bit line mask **174** and the bit line spacer **176** may extend in the first direction, so that the second contact hole **180** may have a rectangular shape extending in the first direction. That is, the rectangular shape may have a long side in the first direction and a short side in the second direction.

The second contact hole **180** may sufficiently expose the first projection portion **110d** and the second projection portion **110e** of the active pattern **110**, and may partially expose the second extension portion **110b** and the third extension portion **110c** of the active pattern **110**. The first projection portion **110d** and the second projection portion **110e** may protrude in the first direction or a direction opposed to the first direction, and may have a rectangular shape or an elliptical shape extending in the first direction.

Referring to FIG. 8A and FIG. 8B, a second contact **182** may be formed to fill the second contact hole **180**.

The second contact **182** may be formed by forming a conductive layer on the second insulating interlayer **170** to fill the first contact hole **180**, and by planarizing an upper portion of the conductive layer until a top surface of the second insulating interlayer **170** is exposed. For example, the conductive layer may be formed using, e.g., a doped polysilicon, a metal, or a metal nitride. Therefore, the second contact **182** may directly contact the active pattern **110**. More particularly, the second contact **182** may directly contact the first projection portion **110d** or the second projection portion **110e** of the active pattern **110**. In this case, a second contact area may be defined as an area where the second contact **182** and the active pattern **110** overlap each other.

The second contact **182** may have a rectangular shape or an elliptical shape extending in the first direction. That is, the second contact **182** may be substantially parallel to the first projection portion **110d** and the second projection portion **110e**, so that a size of the second contact area, i.e., an overlap area between the second contact **182** and either one of the first and second projection portions **110d** and **110e**, may increase. In contrast, when projection portions extend in a direction oblique to the first direction, i.e., non-parallel with respect to a contact parallel to the first direction, a cross section of an overlap area between the contact and the projection portions may have an inclined shape, which has a smaller size than that of a cross section between two parallel elements.

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Therefore, according to example embodiments, the size of the second contact area may be large, so that a contact resistance between the second contact **182** and the active pattern **110** may decrease. Further, the active pattern **110** may provide sufficient process margin for forming the second contact **182** to ensure reliability and to prevent misalignment between the second contact **182** and the active pattern **110**.

Referring to FIG. 9A and FIG. 9B, a lower electrode **192** may be formed on the second insulating interlayer **170** to contact the second contact **182**.

In the process for forming the lower electrode **192**, an etch stop layer **184** and a sacrificial layer **186** may be formed on the second insulating interlayer **170** and the second contact **182**, and the etch stop layer **184** and the sacrificial layer **186** may be partially removed to form an opening **188**. A lower electrode layer may be formed on an inner wall of the opening **188**, and an upper portion of the lower electrode layer may be planarized.

In example embodiments, the sacrificial layer may be formed using, e.g., silicon oxide, and the lower electrode layer may be formed using, e.g., a metal or a metal nitride. That is, the lower electrode layer may be formed using a metal, e.g., copper, aluminum, tungsten, platinum, rhenium, iridium, etc., or a metal nitride, e.g., titanium nitride, tantalum nitride, tungsten nitride, etc. Then, the sacrificial layer **186** may be removed by an etching process.

Referring to FIG. 10A and FIG. 10B, a dielectric layer **194** and an upper electrode **196** may be formed.

The dielectric layer **194** may be formed using a high dielectric material having a dielectric constant substantially higher than that of silicon oxide or silicon nitride. For example, the high dielectric material may include at least one of tantalum oxide, hafnium oxide, aluminum oxide, zirconium oxide, etc. The high dielectric material may be used alone, or may be used as a mixture thereof. The dielectric layer **194** may be formed by a CVD process, a PVD process, an ALD process, and the like.

Then, the upper electrode **196** may be formed using a metal, a metal nitride or doped polysilicon by a CVD process, a PVD process, an ALD process, and the like. The upper electrode **196** may be a cylinder type or may be a thin film type. Therefore, a capacitor **190** may be formed to include the lower electrode **192**, the dielectric layer **194** and the upper electrode **196**.

In example embodiments, a plurality of capacitors **190** may be arranged in the first direction and the second direction, however embodiments are not limited thereto. For example, the capacitors **190** may be arranged in a zigzagged pattern in the first direction.

By performing the above processes, the semiconductor device may be completed.

FIG. 11 illustrates a plan view of a semiconductor device including an active pattern in accordance with other example embodiments. The semiconductor device illustrated in FIG. 11 may be substantially the same as or similar to that illustrated with reference to FIG. 1 except for an active pattern **112**. Thus, like reference numerals refer to like elements, and repetitive explanations thereof will be omitted.

Referring to FIG. 11, the semiconductor device may include the substrate **100** including an active pattern **112** and the isolation layer **120** surrounding the active pattern **112**.

In example embodiments, a plurality of active patterns **112** may be arranged in a first direction substantially parallel to a top surface of the substrate **100** and a third direction oriented obliquely to the first direction. Each of the active patterns **112** may include a plurality of extension portions extending in different directions. In example embodiments, the active pat-

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tern **112** may include a first extension portion **112a**, a second extension portion **112b**, a third extension portion **112c**, a first projection portion **112d**, and a second projection portion **112e**.

The first extension portion **112a** may extend in the first direction. The first extension portion **112a** may have a first width **W1** in a second direction substantially perpendicular to the first direction. The second extension portion **112b** may extend from a first end of the first extension portion **112a** in the third direction, and third extension portion **112c** may extend from a second end of the first extension portion **112a** in a direction opposed to the third direction. In example embodiments, each of the second extension portion **112b** and the third extension portion **112c** may have a width substantially larger than the first width **W1** of the first extension portion **112a**. Further, the first projection portion **112d** may protrude from the second extension portion **112b** in a direction opposed to the first direction, and the second projection portion **112e** may protrude from the third extension portion **112c** in the first direction.

According to example embodiments, the active pattern **112** may include the first extension portion **112a**, the first projection portion **112d**, and the second projection portion **112e** that extend or protrude in the first direction. The first extension portion **112a**, the first projection portion **112d**, and the second projection portion **112e** may overlap contacts that are electrically connected to a capacitor (see FIG. 10B) or a bit line (see FIG. 10B). The contacts may have a rectangular shape or an elliptical shape extending in the first direction, so that the overlapped area between the contacts and the active pattern **112** may increase and the active pattern **112** may provide sufficient process margin to ensure reliability. Each of the second extension portion **112b** and the third extension portion **112c** may have a width substantially larger than the first width **W1** of the first extension portion **112a**. Therefore, a width of a channel region of a gate structure may increase, and an operation speed of the semiconductor device may increase.

FIGS. 12 to 17 illustrate plan views of stages in a method of manufacturing a semiconductor device in accordance with other example embodiments. Some aspects of the methods illustrated in FIGS. 12 to 17 are substantially the same as or similar to those illustrated with reference to FIGS. 2 to 10B. Thus, like reference numerals refer to like elements, and repetitive explanations thereof will be omitted.

Referring to FIG. 12, an upper portion of the substrate **100** may be removed to form the first trench **107**, thereby defining a preliminary active pattern **106**.

The first trench **107** may be formed by forming a mask on the substrate **100**, and removing the upper portion of the substrate **100** using the mask as an etching mask. In example embodiments, the first trench **107** may extend in a first direction, and may extend in a third direction oriented obliquely to the first direction. That is, each of the first trenches **107** may include a plurality of first portions extending in the first direction and a plurality of second portions extending in the third direction that may be arranged alternately and repeatedly.

Therefore, the preliminary pattern **106** may include first extension portion **106a** extending in the first direction and the second extension portion **106b** extending in the third direction. Further, the first extension portion **106a** and the second extension portion **106b** may be arranged alternately and repeatedly. In example embodiment, the first extension portion **106a** may have the first width **W1** in the second direction, and the second extension portion **106b** may have a second width **W2** substantially larger than that of the first extension portion **106a**. As illustrated in FIG. 12, the second width **W2**

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is measured along an oblique direction with respect to the second direction, e.g., a direction perpendicular to the third direction.

Referring to FIG. 13, an upper portion of the substrate 100 may be removed to form the second trench 109, thereby defining the active pattern 112. Then, the isolation layer 120 may be formed to fill the first trench 107 and the second trench 109.

The second trench 109 may be formed by forming a mask on the substrate 100, and removing the upper portion of the substrate 100 using the mask as an etching mask. In example embodiments, the second trench 109 may be disposed to partially overlap the first extension portion 106a of the preliminary active pattern 106. The second trench 109 may be in fluid communication with the first trench 107. Therefore, the active pattern 112 may be defined by the first trench 107 and the second trench 109.

In example embodiments, the active pattern 112 may include the first extension portion 112a, the second extension portion 112b, the third extension portion 112c, the first projection portion 112d, and the second projection portion 112e. The active pattern 112 may be substantially the same as the active pattern 112 described with reference to FIG. 11

Then, an insulation layer may be formed on the substrate 100 to fill the first trench 107 and the second trench 109. Then, an upper portion of the insulation layer may be planarized until the top surface of the substrate 100 is exposed, thereby forming the isolation layer 120.

Referring to FIG. 14, upper portions of the substrate 100 and the isolation layer 120 may be removed to form the third trench 130. Then, the gate insulation layer pattern 140, the gate electrode 145, and the gate mask 150 may be formed to fill the third trench 130.

The third trench 130 may extend in the second direction. In example embodiments, a plurality of third trenches 130 may be arranged in the first direction. More particularly, the third trench 130 overlaps an interface between the first extension portion 112a and the second extension portion 112b or an interface between the first extension portion 112a and the third extension portion 112c. The second extension portion 112b and the third extension portion 112c may have the second width W2, and a channel region, where the gate electrode 145 and the active pattern 112 are overlapped, may have the second width W2. Therefore, a current passing through the channel region may increase, and the operation speed of the semiconductor device may increase.

Referring to FIG. 15, the first insulating interlayer 160 may be formed on the substrate 100, the isolation layer 120, the gate mask 150, and the gate insulation layer pattern 140, and the first contact 165 may be formed through the first insulating interlayer 160. Then, the bit line 172 may be formed to contact the first contact 165.

The first contact 165 may directly contact the first extension portion 112a of the active pattern 112. In this case, a first contact area may be defined as an area where the first contact 165 and the active pattern 112 are overlapped.

The first extension portion 112a of the active pattern 112 may extend in the first direction, and a cross section of the first contact area may have a rectangular shape or an elliptical shape extending in the first direction. Therefore, the size of the first contact area may be large, so that a contact resistance between the first contact 165 and the active pattern 112 may decrease. Further, the active pattern 112 may provide sufficient process margin for forming the first contact 165 to ensure reliability and to prevent misalignment between the first contact 165 and the active pattern 112.

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Referring to FIG. 16, the first insulating interlayer 160 and the second insulating interlayer 170 may be partially removed to form the second contact hole 180. The second contact 182 may be formed to fill the second contact hole 180.

The second contact hole 180 may sufficiently expose the first projection portion 112d and the second projection portion 112e of the active pattern 112. The first projection portion 112d and the second projection portion 112e may protrude in the first direction or a direction opposed to the first direction, and may have a rectangular shape or an elliptical shape extending in the first direction.

The second contact 182 may contact the active pattern 112. More particularly, the second contact 182 may directly contact the first projection portion 112d or the second projection portion 112e of the active pattern 112. In this case, the second contact area may be defined as an area where the second contact 182 and the active pattern 112 are overlapped.

The second contact 182 may have a rectangular shape or an elliptical shape extending in the first direction. That is, the second contact 182 may be substantially parallel to the first projection portion 112d and the second projection portion 112e, so that the size of the second contact area may increase, and a contact resistance between the second contact 182 and the active pattern 112 may decrease. Further, the active pattern 112 may provide sufficient process margin for forming the second contact 182 to ensure reliability and to prevent misalignment between the second contact 182 and the active pattern 112.

Referring to FIG. 17, the capacitor 190 may be formed to be electrically connected to the second contact 182. The processes for forming the capacitor may be substantially the same as those described with reference to FIGS. 9 and 10B.

By performing above processes, the semiconductor device may be completed.

FIG. 18 illustrates a block diagram for explaining a system including a semiconductor device in accordance with example embodiments.

Referring to FIG. 18, a system 200 may include a memory 210, a memory controller 220 controlling the operation of the memory 210, a displaying part 230 outputting information, an interface 240 receiving information, and a main processor 250 controlling the above described parts. The memory 210 may be a semiconductor device in accordance with example embodiments. The memory 210 may be directly connected to the main processor 250 or through a bus. The system 200 may be applied to, e.g., a computer, a portable computer, a laptop computer, a personal portable terminal, a tablet, a cellular phone, a digital music player, etc.

According to some example embodiments, an active pattern may include multiple portions that extend in different directions. That is, the active pattern may include a first extension portion, a first projection portion, and a second projection portion parallel to each other, while portions connecting the first extension portion to each of the first and second projection portions extend obliquely with respect to the first extension portion. The first extension portion, the first projection portion, and the second projection portion may directly contact conductive contacts electrically connected to a capacitor and/or a bit line, so that an overlapped area between the conductive contacts and the active pattern is increased. Therefore, a contact resistance between the conductive contacts and the active pattern may decrease, and the active pattern may provide sufficient process margin to ensure reliability.

In contrast, as an entire active pattern of a conventional semiconductor, e.g., a DRAM, may extend diagonally and be electrically connected to a bit line by a first contact and to a

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capacitor by a second contact, and as a size of the active patterns is decreased, a contact area between the active pattern and the contacts may decrease. As such, a contact resistance between the active pattern and the contacts may increase, thereby reducing the operation speed of the semiconductor device due to RC delay.

Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. A semiconductor device, comprising:
 - a substrate including an active pattern surrounded by an isolation layer, the isolation layer being disposed at an upper portion of the substrate,
 - wherein the active pattern includes:
 - a first extension portion extending in a first direction substantially parallel to a top surface of the substrate,
 - a second extension portion extending from a first end of the first extension portion in a third direction oriented obliquely to the first direction,
 - a third extension portion extending from a second end of the first extension portion in a direction opposed to the third direction,
 - a first projection portion protruding from the second extension portion in a direction opposed to the first direction, the first projection portion being spaced apart from the first extension portion, and
 - a second projection portion protruding from the third extension portion in the first direction, the second projection portion being spaced apart from the first extension portion;
 - a bit line extending in the first direction above the substrate; and
 - a contact connecting the bit line with the first extension portion of the active pattern, wherein the contact comprises a first width, in a second direction perpendicular to the first direction, that is wider than a second width of the first extension portion of the active pattern in the second direction.
2. The semiconductor device as claimed in claim 1, wherein:
 - the first projection portion and the second projection portion are 180 degree rotationally symmetric about an axis passing through a center of the first extension portion in a fourth direction perpendicular to the first direction and the third direction, and
 - the second extension portion and the third extension portion are 180 degree rotationally symmetric about the axis.
3. The semiconductor device as claimed in claim 1, wherein lengths of the first projection portion and the second projection portion in the first direction are smaller than a length of the first extension portion in the first direction.

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4. The semiconductor device as claimed in claim 1, wherein a width of the first extension portion is the same as widths of the second extension portion and the third extension portion.

5. The semiconductor device as claimed in claim 1, wherein a width of the first extension portion is smaller than widths of the second extension portion and the third extension portion.

6. The semiconductor device as claimed in claim 1, wherein the contact comprises a first contact, and wherein the device further comprises:

- a capacitor above the substrate; and
- a second contact connecting the capacitor with the first projection portion or the second projection portion of the active pattern.

7. The semiconductor device as claimed in claim 6, wherein a cross section of a region, where the first contact and the active pattern overlap, has a rectangular shape or an elliptical shape extending in the first direction.

8. The semiconductor device as claimed in claim 6, wherein a cross section of the second contact has a rectangular shape extending in the first direction.

9. The semiconductor device as claimed in claim 1, wherein a plurality of active patterns is arranged in the first direction and the third direction.

10. A method of manufacturing a semiconductor device, the method comprising:

- forming a trench by removing an upper portion of a substrate, thereby defining an active pattern of the substrate; and

forming an isolation layer to fill the trench, wherein the active pattern includes:

- a first extension portion extending in a first direction substantially parallel to a top surface of the substrate,
- a second extension portion extending from a first end of the first extension portion in a third direction, the third direction being oriented obliquely to the first direction,
- a third extension portion extending from a second end of the first extension portion in a direction opposed to the third direction,
- a first projection portion protruding from a first end of the second extension portion in a direction opposed to the first direction, the first end of the second extension portion being spaced apart from the first end of the first extension portion, and
- a second projection portion protruding from a first end of the third extension portion in the first direction, the first end of the third extension portion being spaced apart from the second end of the first extension portion;

forming a contact directly contacting the first extension portion of the active pattern; and

forming a bit line extending in the first direction, the bit line being electrically connected to the contact, wherein the contact comprises a first width, in a second direction perpendicular to the first direction, that is wider than a second width of the first extension portion of the active pattern in the second direction.

11. The method as claimed in claim 10, wherein forming the trench includes:

- forming a first trench extending in the first direction and the third direction alternately and repeatedly, thereby defining a preliminary active pattern; and
- forming a second trench extending in the second direction, the second trench being in fluid communication with the first trench.

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12. The method as claimed in claim 10, wherein the contact comprises a first contact, and wherein the method further comprises:

- forming a second contact directly contacting the first projection portion or the second projection portion of the active pattern; and
- forming a capacitor electrically connected to the second contact.

13. The method as claimed in claim 12, further comprising forming a bit line spacer on a side wall of the bit line after forming the bit line.

14. The method as claimed in claim 13, wherein forming the second contact comprises:

- forming an insulating interlayer above the substrate to cover the bit line;
- forming a contact hole exposing the first projection portion or the second projection portion of the active pattern by removing the insulating interlayer; and
- forming a conductive pattern to fill the contact hole, and wherein the contact hole is disposed not to overlap the bit line or the bit line spacer, the contact hole having a rectangular shape extending in the first direction.

15. A semiconductor device comprising:

- a substrate comprising an active pattern defined by an isolation layer in the substrate,
- wherein the active pattern comprises:
 - a first extension portion extending in a first direction that is perpendicular to a second direction,
 - a first projection portion parallel to and spaced apart from the first extension portion,
 - a second projection portion parallel to and spaced apart from the first extension portion,
 - a second extension portion connecting the first extension portion and the first projection portion, the second extension portion extending in a third direction oriented obliquely to the first direction, and
 - a third extension portion connecting the first extension portion and the second projection portion, the second and third extension portions being parallel to each other;
- a bit line extending in the first direction over the substrate; and
- a contact connecting the bit line with the first extension portion of the active pattern,

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wherein the contact comprises a first width in the second direction that is wider than a second width of the first extension portion of the active pattern in the second direction.

16. The semiconductor device of claim 15, wherein the contact comprises a length in the first direction that is longer than the first width of the contact in the second direction.

17. The semiconductor device of claim 15, wherein:

- the active pattern comprises a first active pattern;
- the contact comprises a first contact;
- the semiconductor device further comprises adjacent second and third active patterns comprising respective first extension portions, first projection portions, second projection portions, second extension portions, and third extension portions;
- the semiconductor device further comprises second and third contacts on the respective first extension portions of the second and third active patterns;
- the first through third contacts of the first through third active patterns comprise different respective positions in the first direction, when viewed in a plan view, and different respective positions in the second direction, when viewed in the plan view; and
- the first through third active patterns at least partially overlap each other in the second direction when viewed in the plan view.

18. The semiconductor device as claimed in claim 15, wherein the contact comprises a first contact, and wherein the device further comprises:

- a capacitor above the substrate; and
- a second contact connecting the capacitor with the first projection portion or the second projection portion of the active pattern.

19. The semiconductor device as claimed in claim 18, wherein longitudinal directions of the first contact and the first extension portion are parallel, and

- wherein an overlap region between the first contact and the first extension portion is rectangular or elliptical, a major axis of the rectangular region or the elliptical region extending in the first direction.

20. The semiconductor device as claimed in claim 18, wherein longitudinal directions of the first contact, second contact, and the first extension portion are parallel.

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